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Interim Report **IR-02-070**

Carbon Dioxide Emission from Soils of Russian Terrestrial Ecosystems

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Approved by

Sten Nilsson
Deputy Director and Leader, Forestry Project

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Contents

Abstract

In order to estimate the total, heterotrophic and autotrophic respiration of Russian soils, a special soil respiration database (SRDB) was compiled based on published results and the author's own measurements. The SRDB includes 95 regional studies and contains 375 records.

It has been found that the contribution of the summer CO_2 flux to the annual carbon dioxide flux (ACDF) is adequately quantified by linear and polynomial regressions. The total soil respirations of individual ecosystems were computed based on these models and the measured summer CO_2 fluxes.

The mean and median values of root respiration by five aggregated land classes were estimated, based on experimental data. By using the obtained results we calculated the heterotrophic and autotrophic components of the total CO_2 by land classes.

The total, heterotrophic and autotrophic ACDF from Russian soils were assessed based on the distrbution of areas of different land classes within the total area of soil units. The total, heterotrophic and autotrophic ACDF from Russian soils were estimated to be 5.67, 2.78 and 2.89 $PgCy^{-1}$, respectively. The maps of total, heterotrophic and autotrophic soil respiration were developed using a geographic information system (GIS) approach. The summarized heterotrophic CO_2 flux and mean weighted heterotrophic respiration of soils by different land use categories and location in different bio-climatic zones were computed using a GIS approach, based on a heterotrophic soil respiration map, a land use/land cover map and a vegetation map.

The results obtained contribute to current understanding of the full terrestrial biota carbon balance of Russia.

Acknowledgments

I am very grateful to the leader of IIASA's Forestry Project, Sten Nilsson, for his critical remarks as well as Anatoly Shvidenko, my supervisor for the summer of 2001, for his cooperation, useful comments and discussions. I appreciated Ian McCallum's great help in using the geographic information system (GIS) approach and providing some calculations. Thanks also goes to my colleagues at the Institute of Physical, Chemical and Biological Problems, Russian Academy of Sciences (Pushchino, Moscow region) for their help on the first stages of data collection for the database and special thanks to V. Lopes de Gerenyu for determining the geographic locations of the sites studied.

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About the Author

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Irina was a participant in the Young Scientists Summer Program (YSSP) during the summer of 2001, assigned to the Forestry Project.

Carbon Dioxide Emission from Soils of Russian Terrestrial Ecosystems

Irina Kurganova

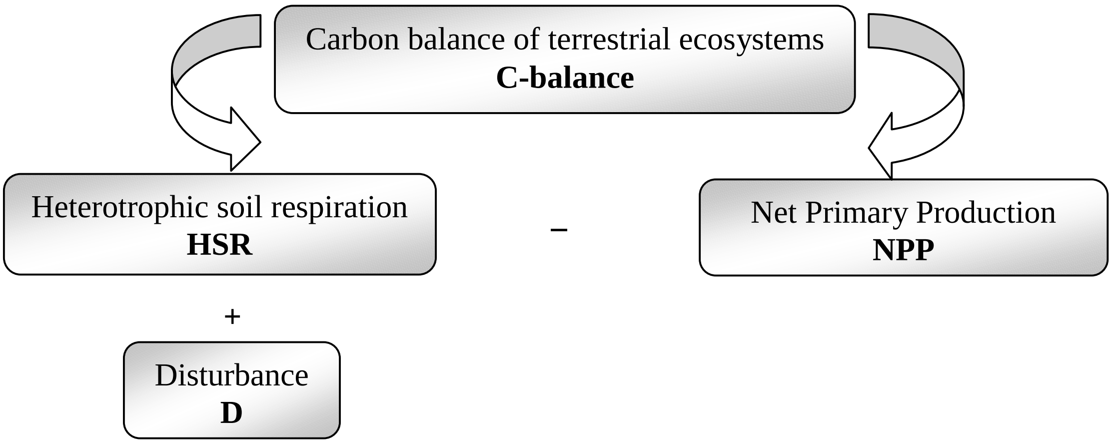
1 Introduction

The carbon cycle is one of the principal global biogeochemical cycles. Changing CO_2 and CH_4 concentration in the earth's atmosphere has a pronounced effect on global climatic change. Comparative to pre-industrial time, CO_2 concentration in the atmosphere is expected to double by 2050–2070 (Zavarzin, 1993). Over the last century the concentration of carbon dioxide has increased by 21% and by the middle of the 21st century it will nearly double again, mainly as a result of fossil fuel combustion (Glazovskaya, 1996). Correspondingly, global air temperature has also increased. An increase in air temperature of 0.5–1.0^{o}C is expected to take place by 2025, and a further increase between 2.5–4.5^{o}C by 2050 (Bolin *et al*., 1986).

The pedosphere is the main natural source of carbon-containing gases (primarily CO_2), which enter the atmosphere and are involved in air circulation. The global annual carbon dioxide flux (ACDF) from the soil of terrestrial ecosystems is estimated to be 50–77 petagrams of carbon (PgC)y^{-1} (Houghton and Woodwell, 1989; Raich and Potter, 1995; Raich and Schlesinger, 1992; Schlesinger, 1977). For comparison, fossil fuel burning adds about 5 $PgCy^{-1}$ to the atmosphere (Marland and Rotty, 1984). Consequently, even small changes in the magnitude of soil respiration could have a large effect on the concentration of CO_2 in the atmosphere.

A prediction of changes in the carbon dioxide concentration in the atmosphere is based on calculating the carbon balance that mostly depends on the ratio between carbon sequestration by plants (net primary productivity, NPP) and its release during soil respiration. A simplified diagram of the carbon balance of terrestrial ecosystems is shown in Figure 1.

The total soil respiration (TSR) flux is the sum of the respiratory activity of autotrophic roots and associated rhizosphere organisms (autotrophic CO_2 flux, AF), heterotrophic bacteria and fungi activities in the organic and mineral soil horizons, and soil faunal activity (Edwards *et al*., 1970). The activity of soil heterotrophic organisms (heterotrophic soil respiration, HSR) is proportional to the decomposition of soil carbon (litter+root detritus+humus). The CO_2 lost from roots and the rhizosphere is tied to the consumption of organic compounds supplied by above ground organisms of plants (Horwath *et al*., 1994). The TSR is higher than the NPP because of the respiration of plant roots and mycorrhizae (Schlesinger and Andrews, 2000).



$$\textbf{C-balance} = (\textbf{HSR} + \textbf{D}) - \textbf{NPP} = (\textbf{TSR} - \textbf{RR} + \textbf{D}) - \textbf{NPP}$$

Figure 1: Simplified carbon balance of terrestrial ecosystems.

In spite of the importance of soil respiration flux in global carbon cycles, the magnitudes of total CO_2 emission from different regions of our planet are poorly quantified. Russia covers approximately an eighth of the earth's land and plays an important role in the global cycling of carbon. The first approximate assessment of total carbon dioxide emission from the whole Russian territory has been made by Kudeyarov *et al*. (1996), which comprises 3.12 PgC per year. However, this study's assessment of CO_2 emission was given only for the growing season, and this estimation was later improved by Kudeyarov and Kurganova (1998). It has been shown that the CO_2 emission during the growing period accounted for 53–88% of the annual CO_2 flux from Russian soils, i.e., approximately 25% of the ACDF is produced by soils outside the growing season. The total ACDF from Russian territory was estimated to be 4.50 PgC. The value of HSR (or net soil source) on Russian territory constitutes from 2.6 to 3.0 $PgCy^{-1}$ according to Kudeyarov's estimation (Kudeyarov, 2000) and 3.2 $PgCy^{-1}$ according to Nilsson *et al*. (2000).

The previous assessments of total CO_2 flux from Russian soils and its components were rather uncertain and did not consider land use impacts. New data concerning annual CO_2 dynamics from different Russian soils and the contribution of root respiration (RR) to ACDF recently became available. Use of these new data and geographic information system (GIS) approaches allows more accurate estimates to be obtained of the total ACDF and its components on Russian territory.

The overall objective of this study was to estimate the total, heterotrophic and autotrophic annual CO_2 flux from Russian soils as accurately as possible and to develop corresponding soil respiration maps.

Our working tasks included:

- Compilation of a soil respiration database (SRDB) for Russian territory based on all available experimental data;
- Assessment of the ACDF from different soils and ecosystems subject to land use;

- Estimation of the heterotrophic and autotrophic components of ACDF taking into account soil types and land cover classes;
- Calculation of the total, heterotrophic and autotrophic annual CO_2 flux from Russian territory; and
- Creation of soil respiration maps based on the soil map at the scale 1:5 million.

2 Soil Respiration Database (SRDB)

2.1 Principles of Organization

The first database on soil respiration for Russian territory contained approximately 80 records and was based on 45 original studies (Kudeyarov *et al.*, 1996). The first computer database for soils of the taiga regions consisted of approximately 230 records (different ecosystems) and more than 65 different sources have been used for organizing this database (Kurganova and Kudeyarov, 1998). In this study, we tried to collect and summarize all of the available experimental data concerning soil respiration of terrestrial ecosystems on Russian territory. The geographical location (latitude and longitude) as well as the mean monthly and mean annual air temperatures were also determined for each of the studied sites.

Soil respiration is often determined by measuring CO_2 flux from the soil surface. Different methods and techniques have been applied to measure soil respiration rates: chamber, profile, absorption, infrared, etc. This diversity generates difficulties in comparing data. In summarizing the available estimates of soil CO_2 efflux we have included the data of field experiments only. We did not include measurements made on soil cores because this technique either modifies or excludes root and mycorrhiza respiration.

The newly created SRDB is based on experimental data from more than 95 different sources and contains approximately 375 records, describing the CO_2 emission rate from various soil and ecosystem types accompanied by a set of location and some environmental parameters. The structure of the SRDB includes:

- Region of investigation;
- Location (latitude and longitude);
- Type of soil;
- Type of vegetation;
- Period of measuring the CO_2 emission rate (years);
- Monthly mean CO_2 emission rates (g CO_2–Cm^{-2} day^{-1});
- Mean summer CO_2 emission rate (g CO_2–Cm^{-2} day^{-1});
- Monthly CO_2 fluxes (kg CO_2–Cha^{-1} month^{-1});
- Seasonal CO_2 fluxes (kg CO_2–Cha^{-1} month^{-1});
- Total annual CO_2 flux (kg CO_2–Cha^{-1} month^{-1});
- Mean monthly and mean annual air temperature, ^{o}C;
- Autotrophic CO_2 flux (kg CO_2–Cha^{-1} month^{-1});
- Heterotrophic annual CO_2 flux (kg CO_2–Cha^{-1} month^{-1});

- Method of measuring the CO_2 emission rate; and
- References.

Unfortunately, there are great differences between different sources in the sets of parameters represented, which lead to information gaps and empty fields for numerous records. The CO_2 fluxes are given in every record, but they refer to different periods of measurements: from 1 to 12 months during 1–3 years. The mean monthly and mean season (mainly summer) values of CO_2 emissions from different soils and ecosystems were calculated. The most important data from the SRDB are presented in Table A1 in the Appendix.

2.2 Analysis of the SRDB

2.2.1 Site location and regions of CO_2 emission measurements

The analyses of the distribution of CO_2 emission measurement sites (Figure 1) allows us to (1) estimate the completeness of our database, and (2) define the regions, which should be priorities for future measurements in order to improve our estimates for the entire country. As can be seen from Figure 2, very few measurements of soil respiration exist for East Siberia and Far East regions, as well as mountainous and semi-arid regions. The lack of measurements in these areas represents a major difficulty in estimating the total Russian CO_2 flux. Most CO_2 emission measurements were carried out in central regions of European Russia (50–60^{o}N, 30–40^{o}E).

2.2.2 Periods and intensity of soil respiration measurements

The first measurements of soil respiration in Russian territory were conducted in 1951–1955. The histogram of the distribution of the number of studies for the period of 1951–2000 is presented in Figure 3.

From the database analysis it can be seen that most of the CO_2 evolution rate's studies were carried out during the summer months (Figure 3). Slightly less measurements of CO_2 emissions were carried out in May and September, and very few observations were conducted during the winter months, November to March. The lack of observations over entire years generates a major difficulty for assessing the total annual CO_2 flux from Russian soils. The geographical coordinates of the studied ecosystems and values of their summer soil respiration are presented in Table A1 in the Appendix.

The number of CO_2 flux measurements was unequal for different land classes (Figure 4). Croplands and forests are the most studied ecosystems. Soil respiration of all land classes in the northern part of Russia are much more poorly quantified than those in the south.

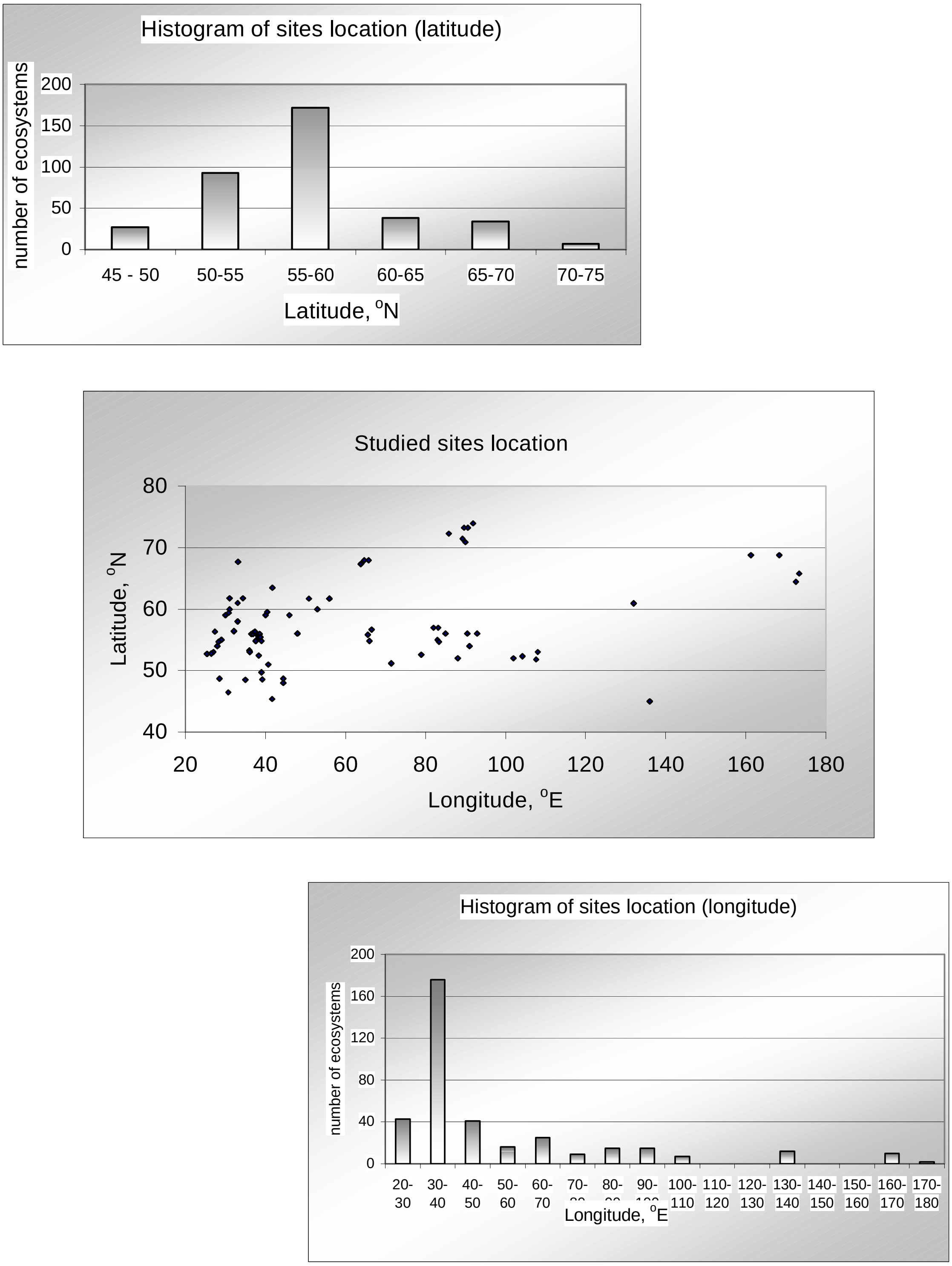
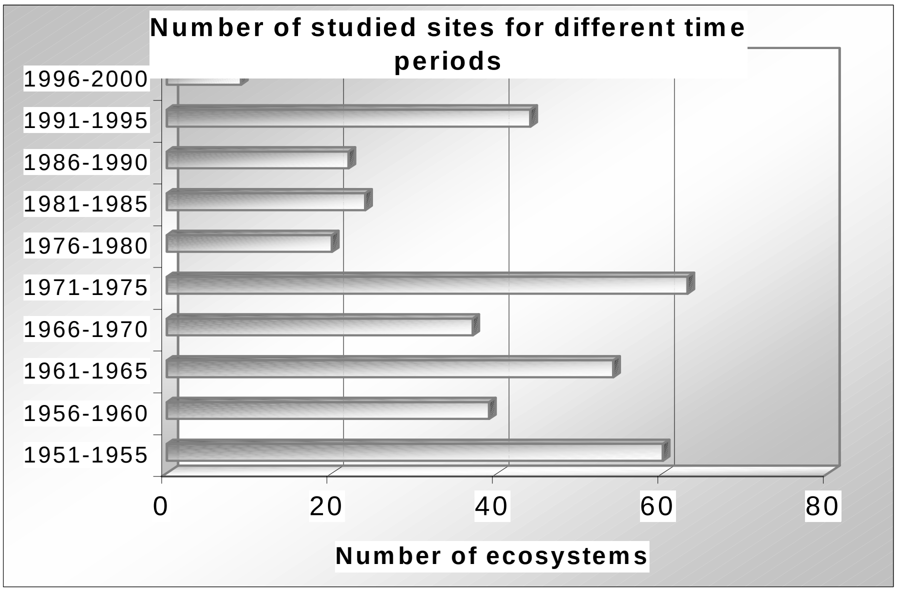


Figure 2: Distribution of CO_2 emission measurement sites.



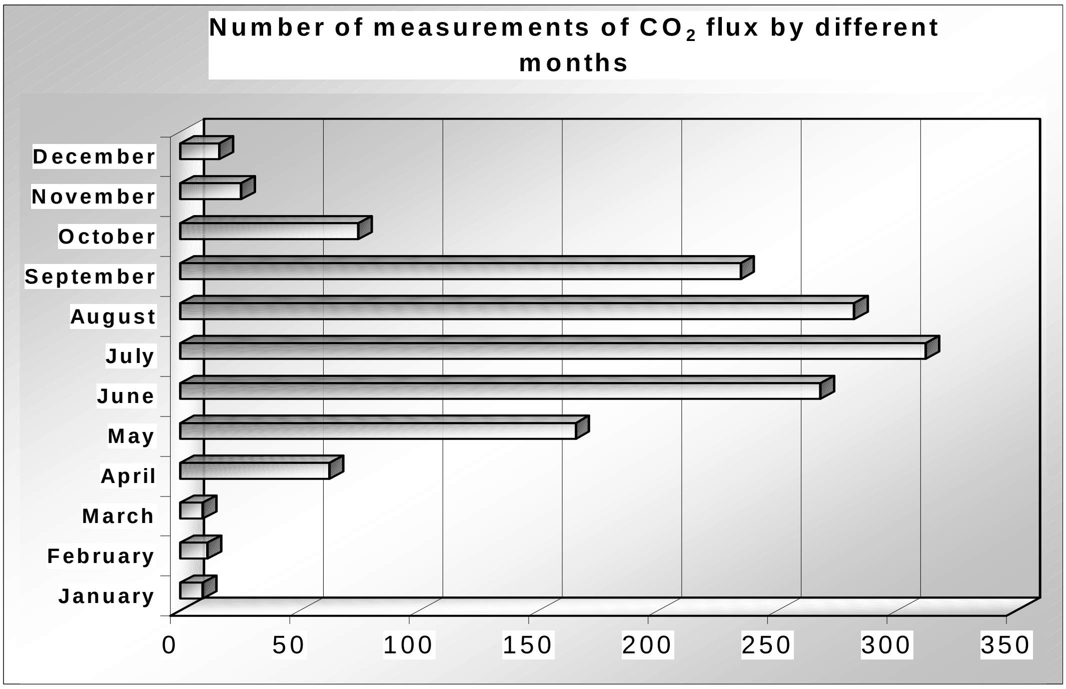


Figure 3: Temporal characteristics of data included in the SRDB.

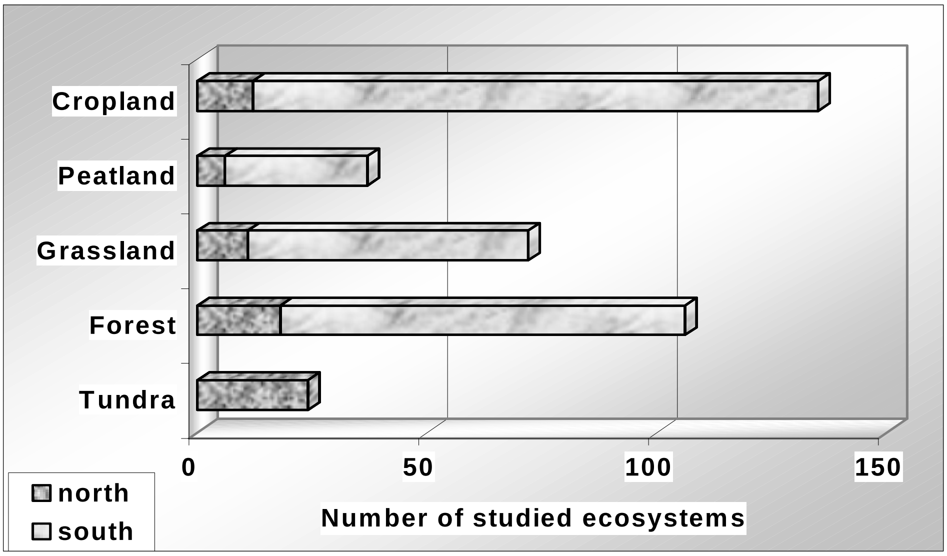


Figure 4: Distribution of studied ecosystems by different land classes.

The analysis of data included in the SRDB showed that:

- Mountainous and semi-arid regions, East Siberia and the Far East should be priorities for future soil respiration flux measurements;
- Croplands and forests are the most studied land classes; soil respiration of all land classes of the Russian north is poorly quantified;
- Most investigations of the CO_2 evolution rate were carried out from May to September; very few observations were conducted during the winter months, November to March.
- The lack of all-year-round CO_2 flux measurements for the majority of Russian regions is a source of major uncertainty in assessing the total annual CO_2 flux from Russian territory. The crucial prerequisite for any substantial improvements for assessing soil respiration in Russia is organizing long-term studies of all-year-round observations of CO_2 fluxes in ecosystems of different bio-climatic zones and different land use patterns.

3 ACDF from Different Ecosystems of the South Taiga Zone

This section contains the results of our measurements of soil CO_2 fluxes provided in five different ecosystems of the southern taiga zone of European Russia. The measurements were provided on an all-year-round basis and to some extent could cover the lack of measurements for the winter fluxes.

3.1 Site Description and CO_2 Emission Measurements

The experimental plots are located in the territory of Prioksko-Terrasny State Reserve (Moscow region, Russia, 54°50'N, 37°35'E) on sandy sod-podzolic soils (Albeluvisols), and 4 kilometers (km) west of Pushchino on clay grey forest soil (Phaeozems). The investigations were conducted in situ over three years under mixed forest (age 90–100 years; C_{total} 1.9%, pH_{H2O} 5.6) and grassland (50 years after cultivation; C_{total} 2.2%, pH_{H2O} 5.4) on Albeluvisol, and under secondary mixed forest (age 45–50 years; C_{total} 2.4%, pH_{H2O} 6.8), grassland (15 years; C_{total} 1.6%, pH_{H2O} 6.5) and arable (winter wheat, C_{total} 1.09%, pH_{H2O} 6.0) on Phaeozems.

CO_2 emissions by soils were measured by a close chamber method over the period November 1997 to October 2000 at 7–10 day intervals. The total number of CO_2 samplings amounted to 105–147 for each site and measurements were done between 9 and 11 in the morning. There were three repetitions during the cold period (November–April) and five during the warm period (May–October). The chamber techniques for these periods were also different. During the warm period we used steel chambers, 10 centimeters (cm) in diameter and 10 cm long, which were inserted to a depth of 3–5 cm into the soil before conducting the gas samplings. In the forest and arable sites the chambers were installed between the growing plants. In grassland the plants were cut before installing the chambers. Thus, the total soil respiration (root respiration + heterotrophic soil respiration) without above ground plant respiration was determined. The dynamics of CO_2 concentrations in the chamber was determined over 45 minutes with 15-minute intervals. During the cold period we used 32 × 32 cm steel bases (with water seal) dug permanently to a depth of 20 cm into the soil and steel boxes 32 × 32 × 15 cm. To exclude the disturbance of snow cover, the bases were built up by special sections as required. The increase of CO_2 concentrations in the chamber was measured over 135 minutes with 45-minute intervals.

The gas samples (20 cm^3) were collected by syringe, transported to the laboratory in hermetically sealed flasks, and analyzed by gas chromatograph. Soil moisture and temperature in the upper soil layer (0–5 cm) were also measured for each sampling date.

3.2 Analysis

The CO_2 flux (emission) was calculated according to the following equation:

$$F_{CO2} = (C-C_0)\cdot H\cdot t^{-1}, \qquad (1)$$

where F_{CO2} is the CO_2-C flux, mg $C\cdot m^{-2}\cdot h^{-1}$; C_0 are the initial head-space concentrations of CO_2-C, mg $C\cdot m^{-3}$; C is the head-space concentration of CO_2-C, mg $C\cdot m^{-3}$, at time t (hour); and H is the height of the head-space layer in the chamber, m.

The monthly CO_2 fluxes from the soils (kg $C\cdot ha^{-1}\cdot month^{-1}$) were calculated using the mean monthly values of CO_2 emissions (g $C\cdot m^{-2}\cdot day^{-1}$) and duration of month (days). The seasonal and annual fluxes were obtained by adding up the monthly fluxes. The monthly, seasonal and annual sums of temperature (Σ T) were determined by simple summation of the mean daily soil temperatures for the definite period.

3.3 Results of Field Observation

3.3.1 Monthly, seasonal and annual CO_2 fluxes

The estimates of mean monthly, seasonal and annual CO_2 fluxes from five different south-taiga ecosystems are presented in Table 1. The average ACDF from sod-podzolic soils were estimated to be 0.68 and 0.92 ton·ha^{-1} under forest and grassland, respectively (coefficient of variation, CV = 29–33%). The annual emissions from grey forest soils ranged from 0.42 to 0.66 kg C·m^{-2} (CV = 19–30%), increasing in the order: arable<grassland<forest. The obtained results agree with estimates reported by other authors (Raich and Schlesinger, 1992; Pajary, 1995). It was found that the grassland ecosystems on Albeluvisols during the whole year were characterized by higher CO_2 emissions than the grassland ecosystems on Phaeozems due to richer grass composition and higher root respiration. The annual CO_2 fluxes from the soils under forests were similar.

Table 1: Mean seasonal and annual CO_2 fluxes from different ecosystems and the contribution of different periods to the ACDF (mean ± sd).

Period	CO_2 fluxes, (*10^{-1}, kg C m^{-2})					Contribution to ACDF, %				
	Sod-podzolic soils		Grey forest soils			Sod-podzolic soils		Grey forest soils		
	Forest	Grass-land	Forest	Grass-land	Arable	Forest	Grass-land	Forest	Grass-land	Arable
Win.	0.6±0.4	0.8±0.5	0.6±0.3	0.4±0.3	0.2±0.0	9.2±3.0	7.8±3.8	8.1±4.1	6.8±3.2	4.4±2.2
Spr.	1.2±0.5	2.0±1.0	1.4±0.6	1.6±0.1	0.5±0.1	18.1±1.6	20.9±5.4	20.8±8.4	25.7±9.8	13.6±3.1
Sum.	3.1±1.0	4.4±0.9	2.8±0.6	3.0±0.6	2.1±0.6	45.6±3.8	48.8±2.6	43.1±3.4	51.6±4.0	51.1±1.2
Aut.	1.9±0.3	2.0±0.4	1.8±0.4	0.9±0.3	1.4±0.6	27.9±12.3	23.8±10.7	28.8±9.4	16.5±9.0	30.9±9.0
Cold	1.5±0.7	1.9±1.0	1.4±0.7	1.3±0.7	0.5±0.0	21.9±3.8	20.1±6.7	20.9±6.7	20.0±7.0	14.1±6.5
Warm	5.3±1.3	7.1±1.3	5.2±0.6	4.6±0.9	3.7±1.3	78.1±3.8	79.9±6.7	79.1±6.7	80.0±7.0	85.9±5.3
Ann.	*6.8±1.9*	*9.2±2.3*	*6.6±1.2*	*5.9±1.6*	*4.2±1.3*					

Win. = winter; Spr. = spring; Sum. = summer; Aut. = autumn; Ann. = annual.

The CV for individual monthly CO_2 flux measurements ranged from 0.7 to 110%. The highest variety of CO_2 flux (CV = 78–110%) was observed in March for most of the ecosystems studied. During the period from April to November the CV rarely exceeded the 50% level. Seasonal fluxes varied less than the monthly ones. The CV averaged 64% for winter fluxes, 37% for spring, 24% for summer, and 28% for autumn. The mean variability of CO_2 flux for cold and warm periods was 52% and 21%, respectively. The variability of monthly, seasonal and annual fluxes can be explained by the different climatic conditions during the studied period.

3.3.2 Contributions of different periods to the ACDF

We calculated the contribution of individual months, calendar seasons, warm and cold periods to the ACDF (Table 1 and Figures 5–7).

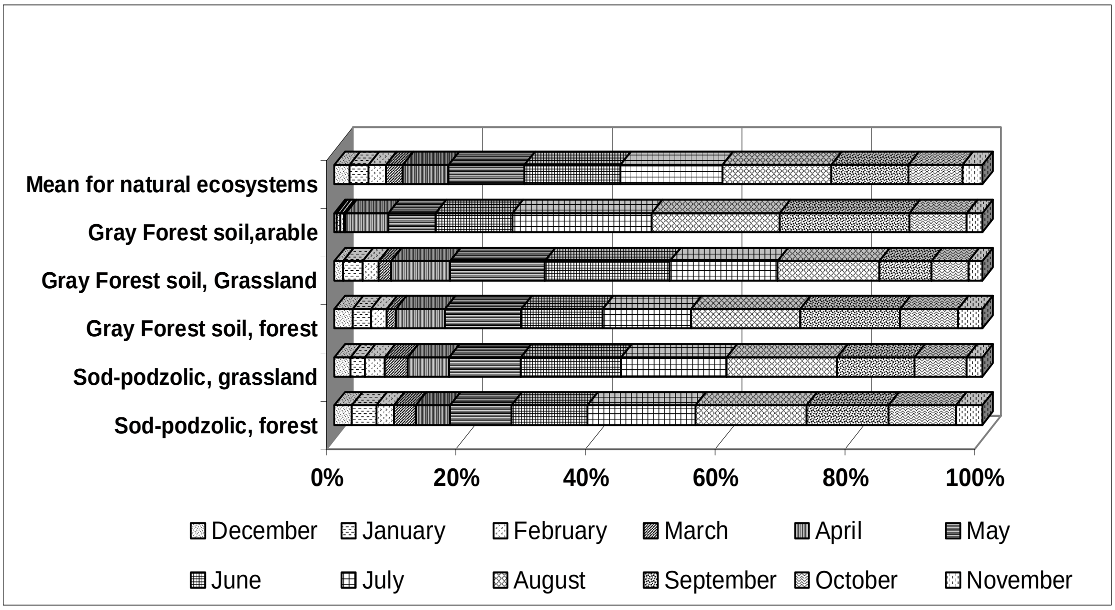


Figure 5: Contributions of different months (Cm, %) to the ACDF for south-taiga ecosystems.

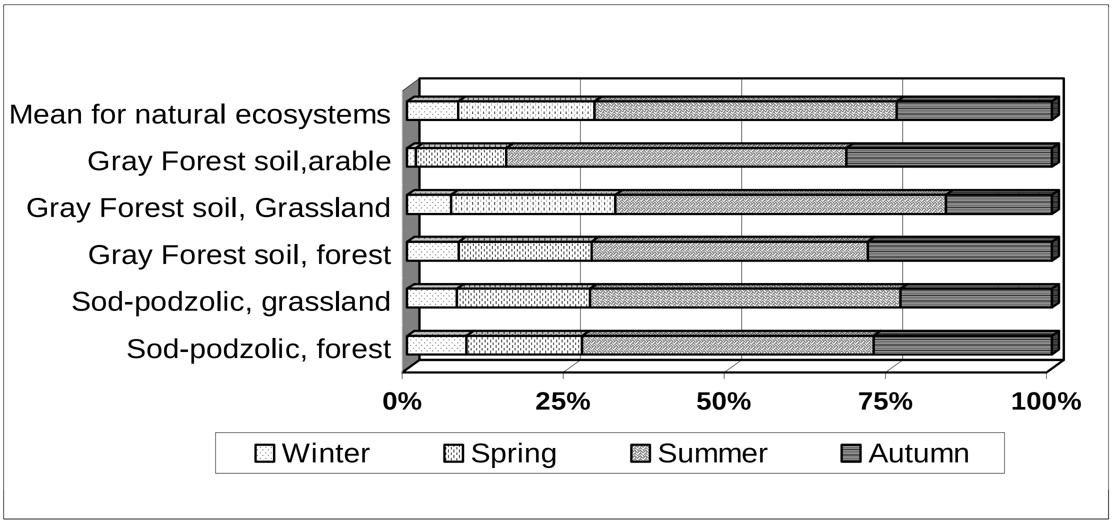


Figure 6: Contributions of different seasons (Cs, %) to the ACDF for south-taiga ecosystems.

The contribution of the cold period (November–April) to annual CO_2 flux was considerable and averaged 21% and 14% for natural and agricultural ecosystems, respectively (Table 1, Figure 7). The CO_2 fluxes comprised approximately a half in summer, a quarter in autumn, a fifth in spring, and a fifteenth in winter of the total ACDF (Table 1, Figure 6). The contribution of individual months to the ACDF varied from 1.5 to 20.6% and depended on the ecosystem type (Figure 5). The obtained estimations agree very well with literature data (Pajary, 1995) and allow us to compute the values of annual CO_2 fluxes for other ecosystems of the south-taiga zone, where studies were conducted during the vegetation or summer seasons.

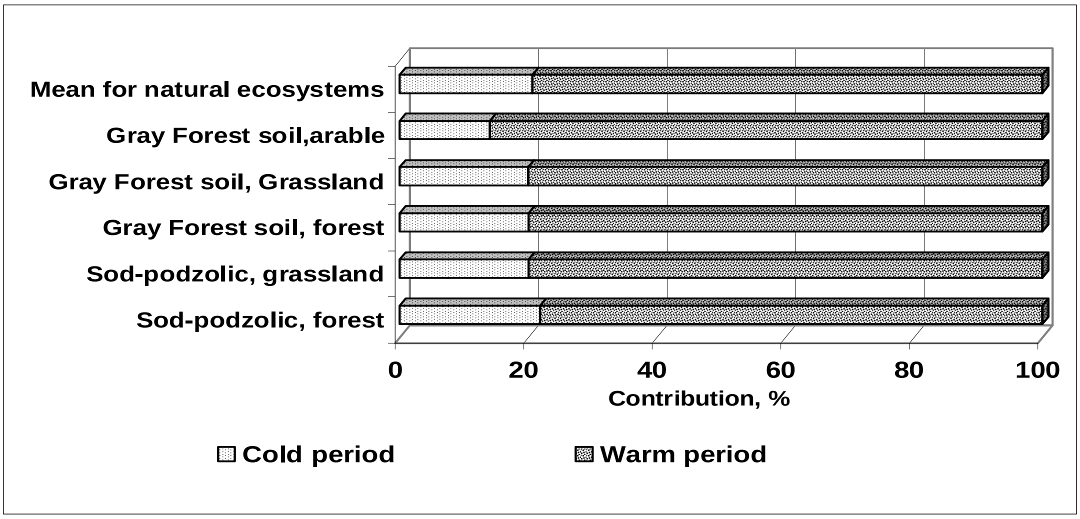


Figure 7: Contribution of cold and warm seasons to the ACDF for the different south-taiga ecosystems.

3.3.3 Assessment of ACDF from other south-taiga ecosystems

As mentioned above, most CO_2 evolution measurements were only carried out for some months of the year. To estimate the ACDF from these soils, the mean monthly CO_2 flux (Fm) is divided by the contribution of this month to the ACDF (Cm; Figure 5). We took into account the type of vegetation and soil when we used the values of Cm in our calculation. The results obtained for several months were averaged. This method of approximation allowed the calculation of the ACDF from soil where measurements were conducted only 1–3 months during the year (CV is approximately 30%).

If measurements of soil respiration were conducted throughout the summer (or vegetation season), we estimated the ACDF using the summer flux (Fs) and the contribution of summer season to the ACDF (Cs, Table 1, Figure 6). Evidently, season-based assessments were more reliable.

Very few measurements of CO_2 emissions were carried out in the period from November to March. In this case we calculated the ACDF by separating CO_2 flux for the warm period (Fp; Table 1, Figure 7) by the contribution of the warm period (Cp) to the ACDF. Among the three methods considered here, this approximation is the most accurate.

Using these approaches we estimated the ACDF for other south-taiga soils (approximately 150 different ecosystems, Table A2 in the Appendix). They ranged from 10 $gC{\cdot}m^{-2}y^{-1}$ (sod-podzolic soils, fallow) to 1650 $gC{\cdot}m^{-2}y^{-1}$ (brownzems, spruce-fir forest) and depended on the soil type and land use. The mean and median values of the ACDF from the south-taiga ecosystems were about 510 and 380 $gC{\cdot}m^{-2}y^{-1}$, respectively.

3.3.4 *The effect of soil temperature on CO_2 fluxes from soil*

The temperature is the best predictor of the annual and seasonal dynamics of the soil respiration rate. On global scales, the monthly and annual CO_2 fluxes correlate significantly with the air temperature (Fung *et al*., 1987; Raich and Schlesinger, 1992). The high positive correlation between CO_2 emissions and soil temperatures was found in natural and agricultural ecosystems of the Russian taiga zone (Kudeyarov and Kurganova, 1998). We tried to quantify the temperature impact on mean CO_2 fluxes from the five studied ecosystems for different time periods (Table 2).

We provided linear regression for predicting the daily CO_2 emission rates from the mean daily soil temperature (Td) in the studied ecosystems. The correlation (R^2) ranged from 0.57 to 0.86 ($P<0.001$) in the soil under natural plant communities and was weaker (0.44) in the arable soil (Table 2).

Table 2: Correlation coefficients (R^2) and coefficients of linear regression models ($F_{CO2} = kT + c$) describing the relationship between mean daily, monthly, seasonal and annual CO_2 fluxes and mean daily soil temperature (T_d) and sums of temperatures for corresponding periods (ΣT).

Fluxes – T	No.	R^2					Coefficients of regression model **k**/c				
		Sod-podzolic		Grey forest			Sod-podzolic soil		Grey forest soil		
		Forest	Grass-land	Forest	Grass-land	Arable	Forest	Grass-land	Forest	Grass-land	Arable
D – T_d	105	0.76[a]	0.86[a]	0.69[a]	0.57[a]	0.44[a]	**7.7**/34	**10.2**/38	**6.8**/31	**6.5**/25	**4.0**/19
M – ΣT	38	0.76[a]	0.86[a]	0.69[a]	0.58[a]	0.45[a]	**1.9**/249	**2.5**/272	**1.6**/228	**1.6**/184	**1.0**/136
S – ΣT	12	0.80[a]	0.90[a]	0.79[a]	0.68[a]	0.55[b]	**1.8**/744	**2.5**/808	**1.5**/756	**1.6**/520	**1.0**/412
P – ΣT	6	0.86[a]	0.91[a]	0.92[a]	0.86[a]	0.59[ns]	**1.9**/1407	**2.5**/1671	**1.8**/1237	**1.5**/1133	**1.1**/559
A – ΣT	3	0.95[ns]	0.55[ns]	0.16[ns]	0.01[ns]	1.00[b]					

D = daily; M = monthly; S = seasonal; P = periods; A = annual; No. = number of measurements; Periods = mean summary CO_2 fluxes; ΣT = warm and cold periods.
[a] = the model is significant at $P< 0.001$; [b] = the model is significant at $0.01<P< 0.05$; [ns] = the model is not significant at 0.05 level.

We found significant linear trends (R^2 = 0.45–0.92, $P< 0.001$) describing the relationship between monthly and seasonal CO_2 fluxes and sums of temperatures for corresponding periods (ΣT). The linear trends were not significant for annual CO_2 fluxes. The obtained results demonstrate that relationships between CO_2 fluxes and soil temperatures were closer in ecosystems on sandy sod-podzolic soils. Grassland ecosystems had the highest sensitivity to temperature fluctuation in soil. The influence of soil temperature on the CO_2 emission rate was weakest on arable grey forest soils. These conclusions may be essential for investigating and predicting how global temperature change will affect carbon dioxide fluxes from different ecosystems.

3.3.5 Estimating monthly and annual CO_2 fluxes from Russian soil using mean monthly air temperature

Fung *et al*. (1987) provided linear regressions for predicting monthly soil respiration from air temperature in different land cover classes: grasslands, temperate/boreal needle-leaved vegetation, temperate boreal broad-leaved vegetation and tropical-subtropical woody vegetation. The coefficient of correlation (R^2) ranged from 0.45 to 0.64.

We attempted to use an identical approach and divided all of the ecosystems of our database into 12 groups subject to bio-climatic zone (polar desert + tundra; forest tundra + northern taiga; southern taiga + temperate zone; steppe + semi-desert) and land cover classes (forest, grassland + pastures, cropland). The correlations between mean monthly CO_2 fluxes and mean monthly air temperature was estimated for each of the above mentioned biome groups. The temperature–respiration relationship were found to be insignificant: R^2 values were very low, 0.03–0.10. This can probably be explained by the lack of experimental data at low temperature (<5–10^{o}C); the majority of the soil respiration measurements were carried out at limited temperature intervals, 10–20^{o}C.

4 Assessment of Total, Heterotrophic and Autotrophic CO_2 Fluxes from Different Ecosystems

4.1 Approaches and Estimation of Total ACDF

The lack of data reporting of all-year-round measurements of CO_2 fluxes from some Russian soils resulted in the necessity to collect additional identical data for soils of other regions (Germany, Finland, Japan, USA, etc). The additionally created database on the ACDF from soils contains data that include monthly, seasonal and annual CO_2 fluxes for 20 different ecosystems. Using these data we calculated the contribution of summer[1] CO_2 emission (Cs) to the ACDF (Table A3 in the Appendix). We determined the values of mean annual air temperature for each site.

It was found that the contribution Fs to the ACDF might be adequately quantified by linear and polynomial regressions (Figure 8). The correlation between these parameters is very close. The R^2 values amount to 0.91 and 0.95 for the linear and polynomial equation, respectively. In our further calculations we used the polynomial regression, as it was more accurate.

Using the obtained model and extracting the mean annual air temperature for the studied ecosystems from the SRDB, we calculated the contribution of summer CO_2 flux to the ACDF for each of the 375 ecosystems (Cs_i). The $ACDF_i$ were estimated according to the following equation:

$$ACDF_i = Fs_i*100 / Cs_i \quad (2)$$

[1] Summer CO_2 emission (Fs) means the sum CO_2 flux during the period from June to August.

where $ACDF_i$ is the total ACDF from individual ecosystems (kg*ha^{-1}*year^{-1}), Fs_i is the summer CO_2 flux from the ecosystem (kg*ha^{-1}*year^{-1}), and Cs_i is the contribution of Fs_i to $ACDF_i$, % (according to the above polynomial model).

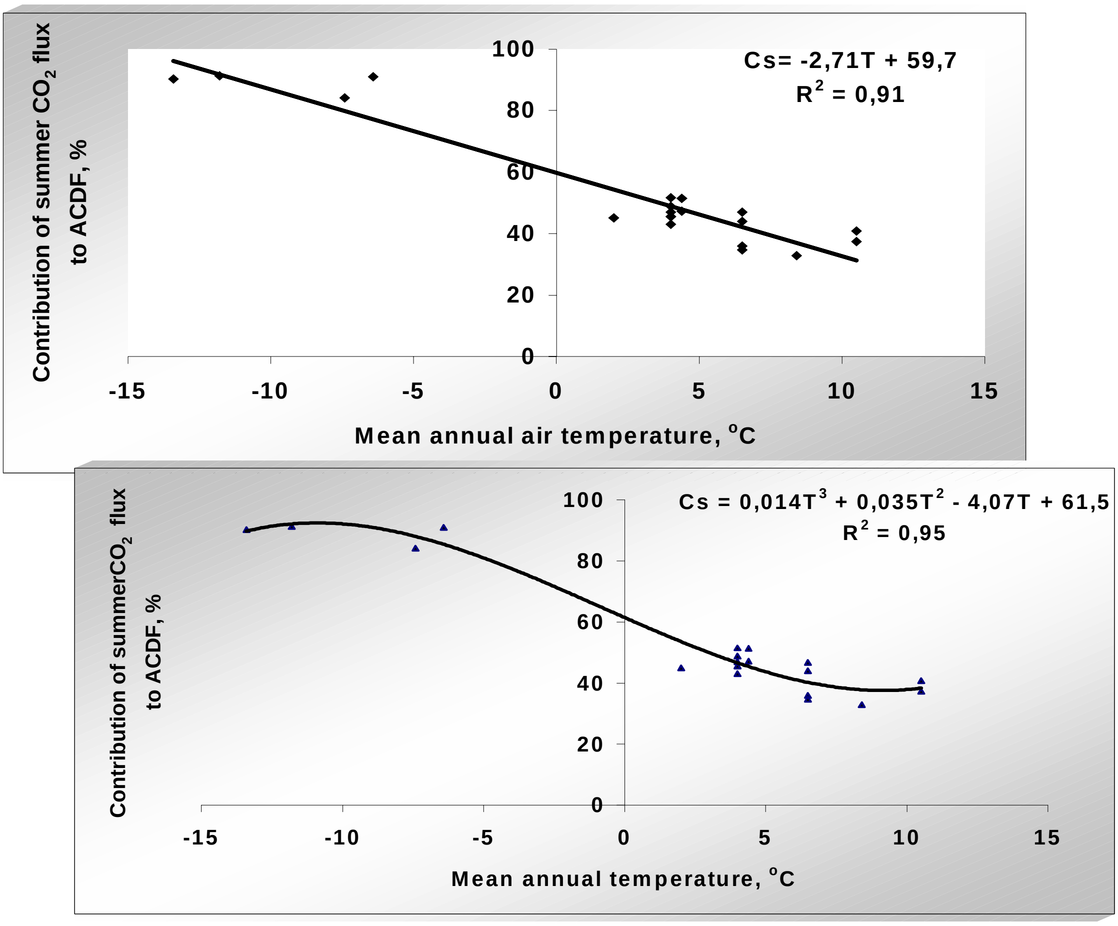


Figure 8: Linear and polynomial models for calculating summer CO_2 flux contribution to the annual flux.

The next steps were:

(1) sorting the data by soil type;

(2) sorting the data by aggregated land classes (tundra, northern and middle taiga forests, southern taiga forests, grassland, cropland, wetlands); and

(3) calculating some statistical parameters (average, standard deviation, median, minimum, maximum) for summer and annual carbon dioxide fluxes.

Some results of these calculations are presented in Table A4 in the Appendix.

4.2 Approaches and Estimation of Heterotrophic and Autotrophic Parts of the ACDF

Soil respiration is determined by measuring the flux of CO_2 from the soil surface. This soil CO_2 efflux is equal to the total soil respiration caused by litter decomposition, respiration of soil micro organisms, fauna, roots and mycorrhizae. Usually the total soil CO_2 flux is presented as the sum of two main components:

- autotrophic CO_2 flux (AF, or root respiration, RR), and
- heterotrophic CO_2 flux (HF).

Numerous publications reported that root respiration can account for as a little as 6% to more than 95% of total soil respiration depending on vegetation type and season of the year. The impacts of land classes were not taken into account in previous estimations of heterotrophic soil respiration (Kudeyarov *et al*., 1996, Kudeyarov, 2000), and root respiration was assumed to be equal to one-third of the total soil respiration for all ecosystems and soils. In order to estimate heterotrophic and autotrophic CO_2 fluxes more accurately, we attempted to take into account the types of ecosystems and land use in our estimation. We collected all of the available published results, which report the values of the AF contribution to total soil respiration (Table A5 in the Appendix).

All of the collected data were combined into five different groups by land class: tundra, northern forests, southern forests, grasslands and croplands (Table 3).

The contribution of root respiration to the total soil respiration varies widely within each land class. We discarded the minimal (<10%) and maximal (>90%) values and recalculated the same statistical parameters (Table 4).

Table 3: Root respiration contribution (C_{AF}) to total soil respiration by land class (before culling).

Land type	Number of studies	Root respiration, % to total			
		Average	Median	Minimum	Maximum
Tundra	5	63	70	33	90
Northern forest	7	62	80	6	90
Southern forest	66	45	46	5	90
Grassland	23	42	37	10	100
Cropland	14	32	27	7	95

Table 4: Root respiration contribution (C_{AF}) to total soil respiration by land class (after culling).

Land type	Number of studies	Root respiration, % to total			
		Average	Median	Minimum	Maximum
Tundra	5	63	70	33	90
Northern forest	6	72	80	43	90
Southern forest	60	48	49	20	90
Grassland	16	45	40	25	80
Cropland	10	38	34	16	75

The results obtained are graphically illustrated in Figure 9.

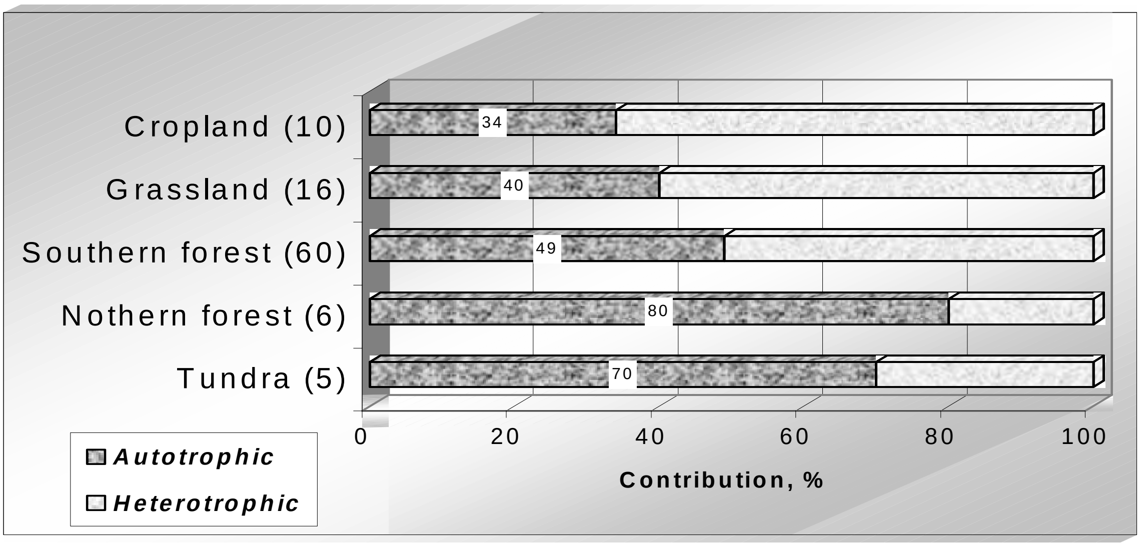


Figure 9: Contribution of root respiration to total soil respiration (median values).

To calculate heterotrophic and autotrophic carbon dioxide fluxes from different soils by the above-mentioned land classes, we used the following equations:

$$ACDF_{AR} = ACDF_i * C_{AR}/100 \quad \text{and} \quad ACDF_{HR} = ACDF_i * C_{HR}/100 \qquad (3)$$

where $ACDF_{AR}$ and $ACDF_{HR}$ are autotrophic and heterotrophic carbon dioxide fluxes, respectively; $ACDF_i$ denotes the total ACDF from a separate ecosystem ($kg*ha^{-1}*year^{-1}$); and C_{AR} and $C_{HR} = 100 - C_{AR}$ are median values of the autotrophic and heterotrophic soil respiration flux contribution to $ACDF_i$, %, respectively.

The calculated results are presented in Table A4 in the Appendix. Due to the lack of data we were not able to estimate the heterotrophic and autotrophic CO_2 fluxes dependently on the season of the year.

5 Estimation of Total, Heterotrophic and Autotrophic ACDF from Russian Territory

5.1 Approaches

Values of total soil respiration and its components depend mainly on soil and vegetation type and climatic conditions of the studied years. To take into account the climatic conditions, it is necessary to have data of long-term soil respiration measurements in different climatic zones. It has been shown that the coefficient of variation for soil CO_2 fluxes caused by meteorological conditions constitutes 19–30% for different ecosystems of the south-taiga zone (Kurganova *et al.*, 2003). The lack of identical data for soils of other regions hinders the reliable assessment of total annual CO_2 flux from Russian territory as a function of climatic conditions.

The estimation of the total carbon dioxide flux from Russian territory is usually based on the conventional approach, namely the integration of CO_2 flux throughout the whole territory depending on the specific CO_2 flux from individual soils and the areas of these soils. To evaluate the total ACDF from Russian territory, the next expression was used:

$$ACDF = \Sigma (ACDF_{ij} * A_j) \qquad (4)$$

where $ACDF_{ij}$ is the arithmetic mean ACDF for j-th soil type, and A_j is the area occupied by j-th soil type.

This approach is based on the simple mean CO_2 flux from identical soils under different vegetation types. It did not take into account that the different ecosystems provide a different contribution to the total CO_2 flux from soils (proportionally the occupied area).

We attempted to carry out a more realistic estimation of carbon dioxide flux by soil types using:

- The soil map of the Russian Soviet Federative Socialist Republic at the scale 1:2.5 M (Fridland, 1988);[2]
- Land use/land cover map of the former Soviet Union at the scale 1:4 M (Yanvaryova, 1989); and
- Vegetation map of the former Soviet Union at the scale 1:4 M (Isachenko *et al.*, 1990).

The majority of Russian soils are mainly located under three categories of land cover (forests, grasslands+pasture, and croplands) in different proportions. The different land use category proportions are unequal for identical soil types located in different bio-climatic zones. Using the GIS approach we overlaid the soil, vegetation and land use/land cover maps. This procedure allowed:

- Computation of the soil areas relating to different land use categories, located within four bio-climatic zones: (1) polar desert and tundra, (2) forest tundra and north taiga forest, (3) south taiga and temperate forests, and (4) steppe and desert; and
- Calculation of the proportions of different land use categories (forests, grasslands and croplands) to total area of soil units located in these bio-climatic zones.

The next equation was used for calculating the weighted mean CO_2 flux from soils:

$$ACDF_{ij}^{w} = fACDF_{ij}*Pf + gACDF_{ij}*Pg + cACDF_{ij}*Pc \qquad (5)$$

where $ACDF_{ij}$ is the weighted mean ACDF for j-th soil type; $fACDF_{ij}$, $gACDF_{ij}$ and $cACDF_{ij}$ are the ACDF for j-th soil type under forest, grassland and cropland, respectively; and Pf, Pg and Pc are the proportion of forests, grasslands and croplands to total area of j-th soil type.

[2] Finally, soil coverage was simplified to 1:5 million, with 136 soil units and 1300 polygons. The lower level of this soil map is called the Russian Soil Map.

The weighted mean values of total, heterotrophic and autotrophic ACDF for 54 soil types (units) were obtained on the basis of our calculation (Table A6 in the Appendix). Experimental data for the other 82 soil types contained in the legend of the soil map of Russia were lacking. Therefore, the values of the ACDF from soils that were similar by genesis and location were used for soil types where CO_2 flux measurements were not conducted.

5.2 Evaluation of the Total ACDF from Russian Territory

The values of total, heterotrophic and autotrophic CO_2 fluxes from separate ecosystems widely varied depending on the soil type and land use (Table A4 in the Appendix).

The total ACDF was estimated according to equation (4), using weighted mean values of the ACDF for each j-th soil type. The areas of soil units were taken from the Russian soil map. The results of the calculations are presented in Table A6 in the Appendix.

Our calculation shows that total, heterotrophic and autotrophic ACDF from Russian territory amounted to 5.67, 2.78 and 2.89 $PgCy^{-1}$, respectively. In other words, the heterotrophic CO_2 flux from Russian terrestrial ecosystems forms approximately half of the total soil respiration.

The obtained value of heterotrophic ACDF from Russian soils (2.78 PgC) is close to the estimation given by Kudeyarov (2000) of 2.6–3.0 $PgCy^{-1}$.

The evaluation of IIASA's Forestry study, comprising 3.2 PgC for 1990 (Nilsson *et al.*, 2000), includes about 0.17 $PgCy^{-1}$ caused by wood decomposition. This means that our result is about 8% less than IIASA's estimate.

5.3 Uncertainties

The assessment of heterotrophic respiration is a typical fuzzy problem due to the lack of complete and statistically reliable experimental data, poor knowledge of some processes, short time series in order to assess interseasonal variability of fluxes, unreliable base for up-scaling, and a number of other reasons. The methods of classical mathematical statistics (such as error propagation theory) can only be used on some stages of the evaluation. In our approximate estimation of uncertainties we used the approach developed by IIASA's Forestry study (Nilsson *et al.*, 2000).

The approach includes:

- application of (modified) error propagation theory with partial use of a priori (personal) probabilities in terms of "summarized errors";
- standard sensitivity analysis to the relevant variations of data, models and methods used;
- expert estimation of the completeness of the accounting and impact of unaccounted processes on the final results; and
- comparison of the results received with the results calculated independently.

By using this approach in a simplified form, we came to the conclusion that the total CO_2 flux is estimated with an uncertainty of about ±6–8%; uncertainties of its autotrophic and heterotrophic parts are ±10–12% (a priori confidential probability of 0.9). This conclusion partially includes expert estimates.

5.4 Soil Respiration Map

The Russian soil map was used as the basis for creating the soil respiration maps. The obtained values of total, heterotrophic and autotrophic CO_2 fluxes from each soil type were aggregated in nine classes according to Table 5. Then the corresponding classes were attached to each soil type from the soil map legend (Table 5). The soil respiration maps were developed using a GIS approach (Figures 10–12).

Table 5: The limits and corresponding classes for values of soil CO_2 fluxes (legends).

Total CO_2 fluxes		Heterotrophic CO_2 fluxes		Autotrophic CO_2 fluxes	
Limits, kgC*ha^{-1}	Class	Limits, kgC*ha^{-1}	Class	Limits, kgC*ha^{-1}	Class
0-500	**1**	0-200	**1**	0-300	**1**
500-1000	**2**	200-500	**2**	300-600	**2**
1000-2000	**3**	500-1000	**3**	600-1000	**3**
2000-3000	**4**	1000-2000	**4**	1000-1500	**4**
3000-4000	**5**	2000-3000	**5**	1500-2000	**5**
4000-6000	**6**	3000-4000	**6**	2000-3000	**6**
6000-8000	**7**	4000-6000	**7**	3000-4000	**7**
8000-10000	**8**	6000-8000	**8**	4000-5000	**8**
10000-13000	**9**	8000-10000	**9**	5000-6000	**9**

The overlaying of heterotrophic soil respiration, vegetation and land use maps allow the computation of the total heterotrophic CO_2 flux and weighted mean heterotrophic respiration of soils by different land cover classes located in different natural climatic zones (Tables 6 and 7).

Table 6: The weighted mean heterotrophic soil respiration (kgCha^{-1}yr^{-1}) from Russian territory by land cover classes and bio-climatic zones.

Zones	Land cover classes				
	Croplands	Forest	Grassland	Wetland	**Grand Total**
Polar desert			45		**45**
Tundra	1009	920	707	795	**728**
Northern Taiga	1058	980	1113	830	**958**
Middle Taiga	1734	1652	1524	1384	**1599**
Southern taiga	2731	2546	2797	2415	**2574**
Temperate forest	2652	2816	3080	2484	**2753**
Steppe	3640	2916	2727	2116	**3449**
Semi-desert	2276	2695	1850	1634	**2089**
Total weighted mean	**3065**	**1730**	**1210**	**1275**	**1708**

Table 7: Heterotrophic ACDF from Russian territory by land cover and bio-climatic zones.

Zones	Parameters	Land Cover Classes: Croplands	Forest	Grasses	Wetland	Grand Total
Polar desert	*HSR, 10^{12}kgC*			*0.1*		*0.1*
	Area, mln km^2	0.00	0.00	0.02	0.00	0.02
Tundra	*HSR, 10^{12}kgC*	*2.7*	*3.5*	*151.7*	*36.9*	*194.8*
	Area, mln km^2	0.03	0.04	2.15	0.46	2.68
Northern taiga	*HSR, 10^{12}kgC*	*2.3*	*138.3*	*32.2*	*50.0*	*222.8*
	Area, mln km^2	0.02	1.41	0.29	0.60	2.33
Middle taiga	*HSR, 10^{12}kgC*	*30.6*	*751.7*	*201.6*	*107.3*	*1091.2*
	Area, mln km$^{2`}$	0.18	4.55	1.32	0.77	6.82
Southern taiga	*HSR, 10^{12}kgC*	*100.2*	*322.1*	*39.9*	*81.4*	*543.6*
	Area, mln km^2	0.37	1.27	0.14	0.34	2.11
Temperate forest	*HSR, 10^{12}kgC*	*75.6*	*74.5*	*13.6*	*2.1*	*165.8*
	Area, mln km^2	0.29	0.26	0.04	0.01	0.60
Steppe	*HSR, 10^{12}kgC*	*422.6*	*27.0*	*58.8*	*2.5*	*510.9*
	Area, mln km^2	1.16	0.09	0.22	0.01	1.48
Semi-desert	*HSR, 10^{12}kgC*	*26.9*	*3.5*	*22.0*	*0.5*	*52.9*
	Area, mln km^2	0.12	0.01	0.12	0.00	0.25
TOTAL	***HSR, 10^{12}kgC***	***660.9***	***1320.6***	***519.9***	***280.8***	***2782.2***
	Area, mln km^2	**2.16**	**7.64**	**4.30**	**2.20**	**16.29**

We can conclude that:

- the territories occupied by forests cause approximately half of the total heterotrophic carbon dioxide flux, croplands a quarter, grasslands a fifth, and wetlands a tenth;
- the highest contributions to the total heterotrophic CO_2 flux are made by territories of the northern taiga forest (27%), steppe croplands (15%) and southern taiga forest (11%);
- the highest intensity of heterotrophic respiration is observed in territories occupied by croplands and forests in the steppe zone (3640 and 2916 kgCha^{-1}year^{-1}, respectively) and grasslands in the temperate forest zone, 3080 kgCha^{-1}year^{-1}; and
- the weighted mean heterotrophic soil respiration decreased in the following order: Steppe>Temperate forest>Southern taiga>Semi desert>Middle taiga>Northern taiga>Tundra>Polar desert.

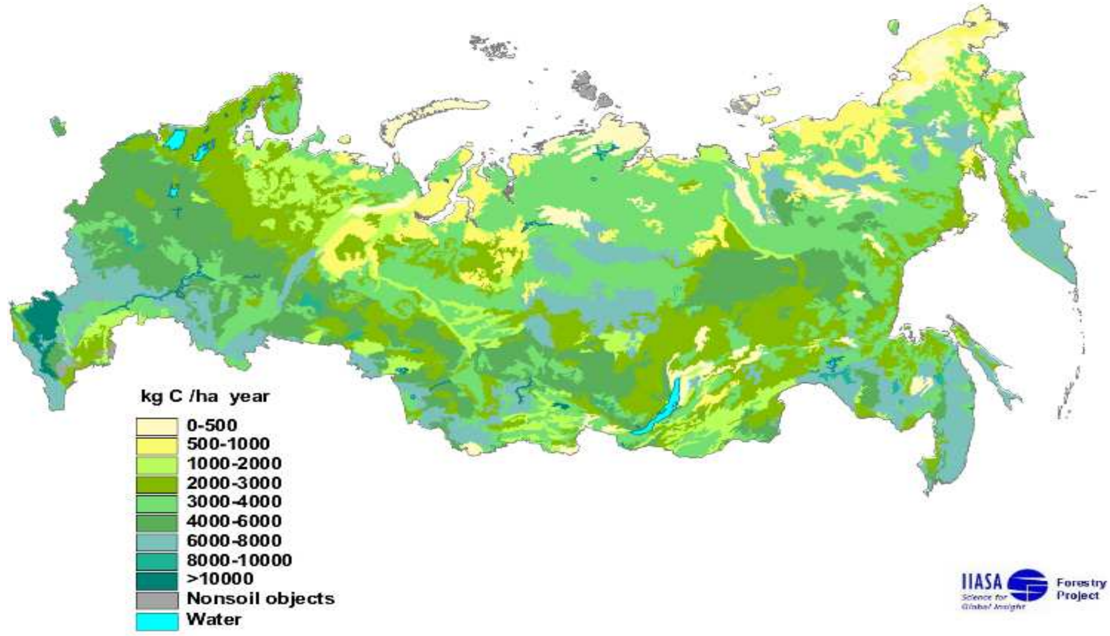


Figure 10: ACDF from Russian soils.

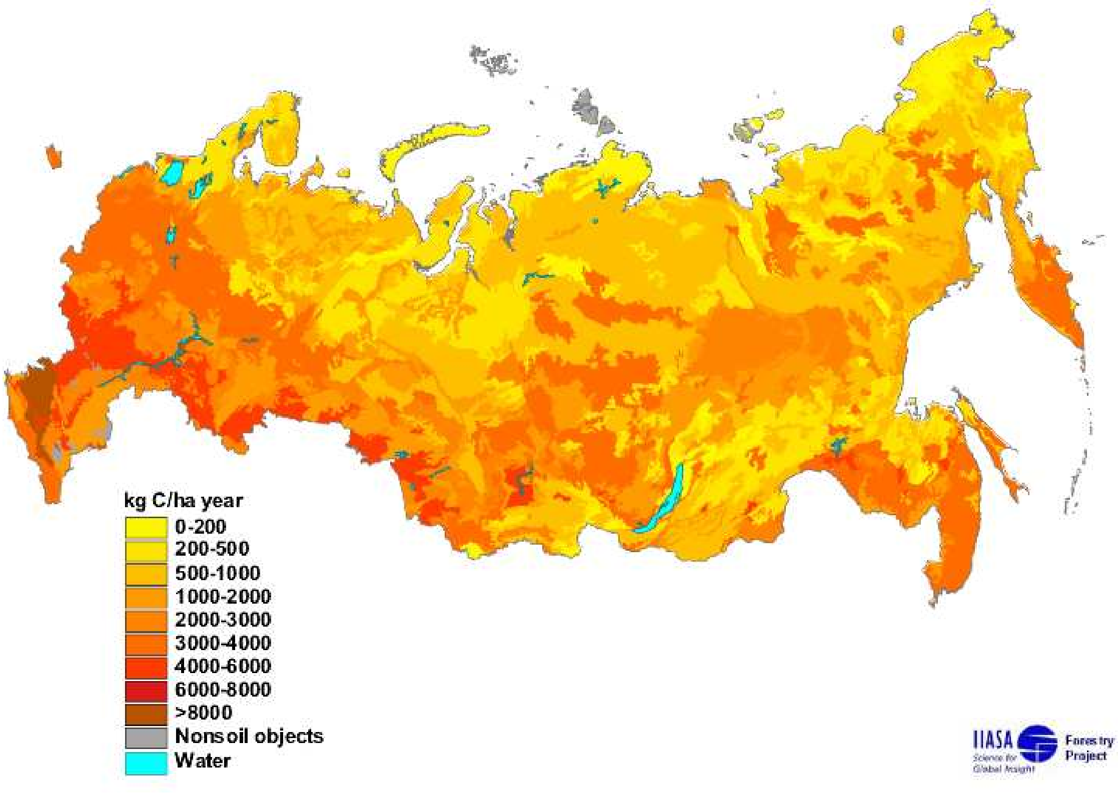


Figure 11: Heterotrophic respiration of Russian soils.

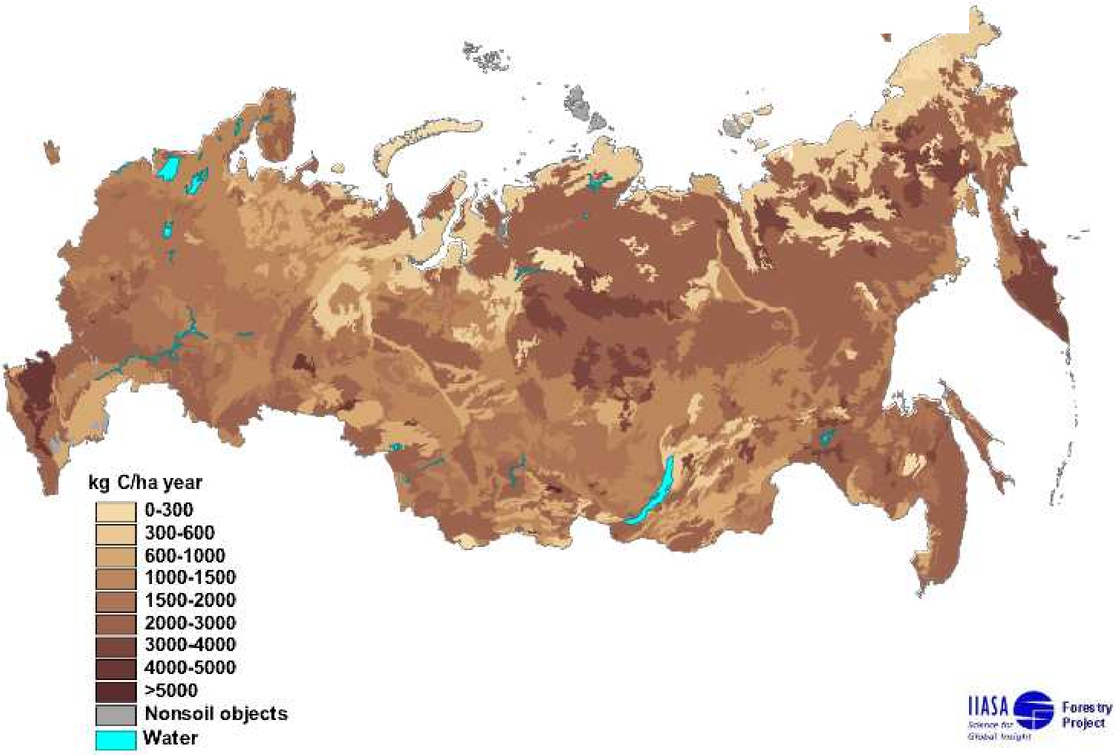


Figure 12: Root respiration of Russian soils.

6 Conclusions

The major conclusion of this study is that the total yearly soil respiration of Russian soils is estimated with uncertainties to be about ±6–8% and the heterotrophic and autotrophic part with uncertainties to be ±10–12% (a priori confidential probability of 0.9) based on all currently available experimental data, soil map at the scale 1:5 million, GIS technologies and appropriate regressions. The major gaps, which should be covered in order to improve these estimations, deal with a limited number and an uneven spatial and temporal distribution of field measurements. Large territories in Northern East Asian Russia are not covered by measurements, and very limited measurements were provided outside the growing season. However, as shown in this study, the impact of this period is significant and cannot be omitted.

The presented results could be approximately addressed to the 1990s — the initial period of the Kyoto Protocol. The CO_2 measurements used for this assessment were provided during the second half of the 20th century and do not contain the impacts of significant climate anomalies that occurred during the last decade. Albeit current science did not answer the still important science questions on the topic and did not reliably quantify the impact of the above anomalies on both the autotrophic and heterotrophic respiration of ecosystems. This feature should be taken into account if the results of this study are used in any full carbon account of Russian terrestrial biota.

The heterotrophic part is estimated to be about 49% of the total CO_2 soil evolution. This is the first estimate of this type based on a systems consideration of the problem, and this estimate is significantly higher than previous estimates of this value for Russian soils.

The annual value of heterotrophic respiration, estimated by this study to be 2.78 $PgCyr^{-1}$, comprises about two-thirds of the NPP of Russian terrestrial ecosystems estimated for approximately the same period (Nilsson *et al*., 2000). This fact points out the tremendous importance of this indicator for future improvements of the full carbon account results for the country. Although our results do not significantly differ from other reported results, there are evident needs for increasing the numbers and the geographical representativeness of long-term measurements in order to provide appropriate modeling of the impacts of the changing environment, land cover and land use changes, and disturbances on this crucial indicator of the biospheric role of Russian terrestrial biota.

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Appendix

Table A1: The geographic coordinates, summer and annual carbon dioxide fluxes from Russian terrestrial ecosystems.

Table A2: The contribution of summer CO_2 flux to ACDF (C_{Fs}) subject to mean annual air temperature.

Table A3: The total heterotrophic and autotrophic soil respiration of Russian terrestrial ecosystems.

Table A4: The root/rizosphere contributions (RC) to total respiration by vegetation type and experimental approach.

Table A5: Total heterotrophic and autotrophic annual carbon dioxide flux from Russian soils.

Table A6: Total heterotrophic, autrotrophic ACDF and corresponding classes for Russian soils (in accordance with the soil map of Russia).

Table A1: The geographic coordinates, summer and annual carbon dioxide fluxes from Russian terrestrial ecosystems.

No.	Location N Latitude	Location E Longitude	Soil	Vegetation	Observed Summer Fs, Kg/ha	Estimated ACDF kg/ha	Reference
1	61.67	56.00	Podzol ferriferouse	Pine forest, 150–200 years	1546	2487	Frolova (1961)
2	61.67	56.00	Podzol ferriferouse	Pine forest remainder, 150–200 years	1242	1998	Frolova (1961)
3	61.67	56.00	Podzol ferriferouse	Clearcut pine forest (17 years renewal)	1858	2990	Frolova (1961)
4	61.67	56.00	Podzol ferriferouse	Clearcut pine forest (17 years without renewal)	837	1347	Frolova (1961)
5	61.67	56.00	Podzol ferriferouse	Clearcut pine forest (3 years renewal)	626	1007	Frolova (1961)
6	61.67	56.00	Strongly-Podzolic soil	Spruce forest (80–100 years)	2448	3939	Frolova (1961)
7	61.67	56.00	Strongly-Podzolic soil	Spruce forest (130–150 years)	2826	4547	Frolova (1961)
8	61.67	56.00	Strongly-Podzolic soil	Young spruce forest (15–30 years)	1796	2890	Frolova (1961)
9	60.00	31.00	Sod-weakly-podzolic soil	Spruce forest (with a touch of birch and aspen)	2230	4810	Pestryakov and Vasil'ev (1977)
10	60.00	53.00	Sod-medium-podzolic	Mixed forest (spruce, fir, aspen, birch)	2475	4461	Tyulin and Kuznetsov (1971)
11	56.08	37.50	Sod-medium-podzolic	Mixed forest	4754	9687	Nikolaeva (1970)
12	56.00	48.00	Podzolic soil	Pine forest (lichen, 2 class of age)	614	1362	Smirnov (1958)
13	56.00	48.00	Podzolic soil	Glade of dry lichen pine forest	531	1177	Smirnov (1958)
14	56.00	48.00	Podzolic soil	Clearcut pine forest	530	1175	Smirnov (1958)
15	56.00	48.00	Sod-medium-podzolic	Spruce forest (compound)	1343	2977	Smirnov (1958)
16	56.00	48.00	Sod-medium-podzolic	Nursery forest (4-years pine)	1117	2476	Smirnov (1958)
17	56.00	48.00	Sod-medium-podzolic	Spruce forest (compound)	1412	3129	Smirnov (1958)
18	56.00	48.00	Sod-medium-podzolic	Spruce forest (green moss)	362	801	Smirnov (1958)
19	56.00	48.00	Podzolic	Pine forest (lichen)	605	1342	Smirnov (1958)
20	56.00	48.00	Sod-weakly-podzolic	Pine forest (red bilberries)	902	1999	Smirnov (1958)
21	59.00	40.00	Peats boggy (low)	(sedge, sphagnum peat)	1295	2432	Vompersky (1968)
22	59.00	40.00	Peats boggy (low)	(wood-sedge peat)	1169	2194	Vompersky (1968)
23	59.00	40.00	Peats boggy (low)	(sphagnum medium peat)	753	1414	Vompersky (1968)
24	59.00	40.00	Peats boggy (transitional)		768	1442	Vompersky (1968)
25	59.00	40.00	Peats boggy (transitional)	(woody-aspen)	1162	2181	Vompersky (1968)
26	58.00	33.00	Sod-cryptopodzolic	Spruce forest (30 year)	2874	6130	Grishina *et al.* (1979)
27	58.00	33.00	Sod-cryptopodzolic	Spruce forest (80 year)	3493	7449	Grishina *et al.* (1979)
28	63.50	41.75	Podzol	Spruce forest (bilberry)	1195	2057	Parshevnikov (1960)
29	63.50	41.75	Podzol	Clearcut spruce forest (bilberry)	1287	2215	Parshevnikov (1960)
30	63.50	41.75	Podzol	Pine forest (moss-lichen)	1298	2233	Parshevnikov (1960)

Table A1: continued.

No.	Location N Latitude	Location E Longitude	Soil	Vegetation	Observed Summer Fs, Kg/ha	Estimated ACDF kg/ha	Reference
31	63.50	41.75	Podzol	Clearcut pine forest (moss-lichen)	793	1365	Parshevnikov (1960)
32	54.83	37.58	Gray forest soil	Grassland (coenoces)	5162	11071	Larionova *et al*. (2000)
33	54.83	37.58	Gray forest soil	Grassland (soil)	902	1935	Larionova *et al*. (2000)
34	54.83	37.58	Gray forest soil	Mixed forest (coenoces)	3274	7023	Larionova *et al*. (2000)
35	54.83	37.58	Gray forest soil	Mixed forest (soil+litter)	1340	2875	Larionova *et al*. (2000)
36	54.83	37.58	Gray forest soil	Mixed forest (soil)	1256	2694	Larionova *et al*. (2000)
37	54.83	37.58	Gray forest soil	Mixed forest	2852	6116	Lopes de Gerenyu *et al*. (2001)
38	54.83	37.58	Gray forest soil	Grassland	3010	6455	Lopes de Gerenyu *et al*. (2001)
39	54.83	37.58	Sod-weakly-podzolic soil	Mixed forest	3116	6684	Lopes de Gerenyu *et al*. (2001)
40	54.83	37.58	Sod-weakly-podzolic soil	Grassland	4388	9412	Lopes de Gerenyu *et al*. (2001)
41	60.00	31.00	Sod-weakly-podzolic soil	Maize	2387	5149	Pestryakov and Vasil'ev (1977)
42	60.00	53.00	Sod-medium-podzolic	Spring crops	1344	2422	Tyulin and Kuznetsov (1971)
43	60.00	53.00	Sod-medium-podzolic	Wheat	1803	3250	Tyulin and Kuznetsov (1971)
44	60.00	53.00	Sod-medium-podzolic	Oats	2916	5255	Tyulin and Kuznetsov (1971)
45	60.00	53.00	Sod-medium-podzolic	Barley	2597	4680	Tyulin and Kuznetsov (1971)
46	67.42	64.00	Sod-surfacely gleic	Perennial grass (1 year)	1295	1515	Stenina (1976)
47	67.42	64.00	Sod-surfacely gleic	Perennial grass (15 years)	1000	1170	Stenina (1976)
48	67.42	64.00	Sod-surfacely gleic	Oats	837	980	Stenina (1976)
49	58.00	33.00	Sod-podzolic-contact-gleic	Swede	2117	4516	Grishina and Morgun (1978)
50	58.00	33.00	Sod-podzolic-contact-gleic	Barley	2605	5556	Grishina and Morgun (1978)
51	58.00	33.00	Sod-podzolic	Swede	2325	4959	Grishina and Morgun (1978)
52	58.00	33.00	Sod-podzolic	Barley	2765	5897	Grishina and Morgun (1978)
53	58.00	33.00	Sod-medium-podzolic-contact-gleic	Barley	2133	4550	Grishina and Morgun (1978)
54	58.00	33.00	Sod-strongly-podzolic-contact-gleic	Barley	2172	4632	Grishina and Morgun (1978)
55	58.00	33.00	Crypto-podzolic-deep-gleic	Swede	1714	3656	Grishina and Morgun (1978)
56	58.00	33.00	Crypto-podzolic	Swede	1636	3489	Grishina and Morgun (1978)
57	56.17	37.00	Sod-medium-podzolic	Fir forest (complex)	3404	6976	Yastrebov (1958)
58	56.17	37.00	Meadow-sod	Grassland	13984	28658	Yastrebov (1958)
59	56.17	37.00	Meadow-sod	Grassland	21620	44306	Yastrebov (1958)
60	56.08	37.50	Sod-medium-podzolic	Perennial grass (4 years)	3685	7508	Nikolaeva (1970)

Table A1: continued.

No.	Location N Latitude	E Longitude	Soil	Vegetation	Observed Summer Fs, Kg/ha	Estimated ACDF kg/ha	Reference
61	56.08	37.50	Sod-medium-podzolic	Perennial grass (2 years)	3726	7591	Nikolaeva (1970)
62	56.08	37.50	Sod-medium-podzolic	Winter rye with trefoil	3608	7351	Nikolaeva (1970)
63	56.08	37.50	Sod-medium-podzolic	Stuble of oats and vetch	2572	5240	Nikolaeva (1970)
64	55.42	38.33	Sod-medium-podzolic	Fallow	1281	2700	Makarov and Frenkel' (1956)
65	55.42	38.33	Sod-medium-podzolic	Perennial grass (1 year)	2965	6252	Makarov and Frenkel' (1956)
66	55.42	38.33	Sod-medium-podzolic	Winter rye	2847	6005	Makarov and Frenkel' (1956)
67	55.92	36.50	Sod-medium-podzolic	Winter rye	3453	7036	Makarov *et al*. (1971)
68	55.92	36.50	Sod-medium-podzolic	Barley	730	1488	Makarov *et al*. (1971)
69	55.92	36.50	Sod-medium-podzolic	Fallow	2800	5705	Makarov *et al*. (1971)
70	56.33	37.42	Humus-peaty-ferrigenous	Perennial grass (2 year)	5377	10956	Makarov *et al*. (1971)
71	56.33	37.42	Humus-peaty-ferrigenous	Perennial grass	5276	10749	Makarov (1960; 1962)
72	56.33	37.42	Humus-peaty-ferrigenous-calcareous	Perennial grass	5487	11179	Makarov (1960)
73	55.42	38.33	Sod-moderately-podzolic	Fallow	736	1552	Makarov (1952)
74	55.42	38.33	Sod-moderately-podzolic	Perennial grass	4893	10318	Makarov (1952)
75	55.42	38.33	Sod-moderately-podzolic	Oats	4397	9273	Makarov (1952)
76	55.42	38.33	Sod-moderately-podzolic	Potato	3848	8115	Makarov (1952)
77	55.42	38.33	Sod-ferrigenous	Crops	2298	4846	Makarov (1952)
78	55.92	36.50	Sod-moderately-podzolic	Fallow	614	1258	Makarov (1966)
79	55.92	36.50	Sod-moderately-podzolic	Barley	1996	4091	Makarov (1966)
80	55.92	36.50	Sod-moderately-podzolic	Alfalfa	2395	4908	Makarov (1966)
81	56.00	48.00	Sod-moderately-podzolic	Trefoil (2 year)	1786	3959	Smirnov (1958)
82	52.67	25.42	Peat-boggy	Fallow	581	1499	Belkovskyand Reshetnik (1981)
83	52.67	25.42	Peat-boggy	Perennial grass	1302	3357	Belkovskyand Reshetnik (1981)
84	52.67	25.42	Peat-boggy	Winter rye	1226	3163	Belkovskyand Reshetnik (1981)
85	52.67	25.42	Peat-boggy	Potato	862	2224	Belkovskyand Reshetnik (1981)
86	54.00	28.00	Peat-boggy (low)	Cropland	6705	15657	Lavrichenko *et al*. (1980)
87	54.83	37.58	Forest gray soil	Winter wheat	1400	3003	Larionova and Rozonova (1993)
88	54.83	37.58	Forest gray soil	Buckwheat	879	1885	Larionova *et al*. (2000)
89	54.83	37.58	Forest gray soil	Buckwheat	953	2045	Larionova *et al*. (2000)
90	54.83	37.58	Forest gray soil	Winter wheat	2146	4603	Lopes de Gerenyu *et al*. (2001)

Table A1: continued.

No.	Location N Latitude	Location E Longitude	Soil	Vegetation	Observed Summer Fs, Kg/ha	Estimated ACDF kg/ha	Reference
91	61.75	31.00	Podzolic	Forest	1085	2098	Zavarzin and Pogodina (1979)
92	61.75	31.00	Podzolic	Grassland	3012	5823	Zavarzin and Pogodina (1979)
93	61.75	31.00	Podzolic	Forest	1083	2094	Zavarzin and Pogodina (1979)
94	61.75	31.00	Podzolic	Grassland	2777	5368	Zavarzin and Pogodina (1979)
95	59.00	46.00	Sod-podzolic	Spruce forest	4359	9873	Roostalu *et al*. (1970)
96	55.92	38.50	Sod-podzolic	Oak-spruce (sedge)	3811	8038	Karpachevsky (1977)
97	55.92	38.50	Sod-podzolic	Linden-spruce-green moss	3169	6684	Karpachevsky (1977)
98	55.92	38.50	Sod-podzolic	Oak-spruce (spruce+sedge)	3819	8054	Karpachevsky (1981)
99	55.92	38.50	Sod-podzolic	Oak-spruce (oak+lungwort)	3243	6840	Karpachevsky (1981)
100	55.92	38.50	Sod-podzolic	Oak-spruce (birch)	3310	6981	Karpachevsky (1981)
101	55.92	38.50	Sod-podzolic	Oak-spruce (aspen+aegopodium)	4063	8568	Karpachevsky (1981)
102	55.92	38.50	Sod-podzolic	Oak-spruce (fern)	3539	7462	Karpachevsky (1981)
103	55.92	38.50	Sod-podzolic	Spruce forest (sedge)	3138	6618	Karpachevsky (1981)
104	55.92	38.50	Sod-podzolic	Spruce forest (oak+lungwort)	2939	6198	Karpachevsky (1981)
105	55.92	38.50	Sod-podzolic	Spruce forest (birch)	2669	5629	Karpachevsky (1981)
106	55.92	38.50	Sod-podzolic	Spruce forest (aspen+aegopodiumbirch)	3757	7924	Karpachevsky (1981)
107	55.92	38.50	Sod-podzolic	Spruce forest (fern)	3033	6395	Karpachevsky (1981)
108	56.08	37.50	Sod-podzolic	Mixed forest	690	1406	Bondarev (1965)
109	55.00	29.00	Sod-podzolic	Oak	1484	3464	Shkurinov (1972)
110	55.00	29.00	Sod-podzolic	Spruce forest	1825	4261	Shkurinov (1972)
111	55.42	38.33	Sod-medium-podzolic	Forest	2996	6318	Makarov and Frenkel' (1956)
112	55.42	38.33	Sod-medium-podzolic	Glade	4780	10081	Makarov and Frenkel' (1956)
113	55.92	36.83	Sod-medium-podzolic	Mixed forest (birch, aspen, spruce, oak)	2291	4695	Makarov (1966)
114	56.42	32.08	Sod-medium-podzolic	Pine forest (lichen)	1597	3445	Vompersky (1994)
115	56.42	32.08	Sod-medium-podzolic	Spruce forest	1462	3153	Vompersky (1994)
116	56.42	32.08	Peat-boggy	Pine forest (shrubs+sphagnum)	1076	2321	Vompersky (1994)
117	56.42	32.08	Peat-boggy	Alder forest (fern)	965	2083	Vompersky (1994)
118	56.42	32.08	Peat-boggy	Complex	1051	2267	Vompersky (1994)
119	59.00	30.00	Peat-boggy	Pine forest (sphagnum+bilberry)	748	1614	Vompersky *et al*. (1975)
120	59.00	30.00	Peat-boggy	Pine forest (sphagnum)	1137	2452	Vompersky *et al*. (1975)

Table A1: continued.

No.	Location N Latitude	Location E Longitude	Soil	Vegetation	Observed Summer Fs, Kg/ha	Estimated ACDF kg/ha	Reference
121	59.00	30.00	Peat-boggy	Pine forest (sphagnum+bilberry)	1014	2188	Vompersky *et al*. (1975)
122	59.00	30.00	Peat-boggy	Pine forest (green moss+grass)	1839	3967	Vompersky *et al*. (1975)
123	59.00	30.00	Peat-boggy	Pine forest (shrubs+sphagnum)	1550	3344	Vompersky *et al*. (1975)
124	59.00	30.00	Peat-boggy	Pine forest (sedge+sphagnum)	1362	2937	Vompersky *et al*. (1975)
125	59.00	30.00	Peat-boggy	Spruce forest	702	1515	Vompersky *et al*. (1975)
126	59.00	30.00	Peat-boggy	Pine forest	989	2132	Vompersky *et al*. (1975)
127	59.00	30.00	Peat-boggy	Spruce forest	757	1633	Vompersky *et al*. (1975)
128	54.00	28.00	Peat soil	Natural haymaking	552	1289	Zimenko and Samsonova (1971)
129	54.00	28.00	Peat soil	Virgin lands	368	859	Zimenko and Samsonova (1971)
130	54.67	28.33	Peat-boggy	Spruce forest (grassy)	512	1195	Misnik *et al*. (1991)
131	54.67	28.33	Peat-boggy	Spruce forest (birch-grassy)	656	1533	Misnik *et al*. (1991)
132	54.67	28.33	Peat-boggy	Spruce forest (pine-sphagnum)	903	2109	Misnik *et al*. (1991)
133	54.67	28.33	Peat-boggy	Spruce forest (pine-grassy)	855	1997	Misnik *et al*. (1991)
134	63.50	41.75	Podzol	Pine forest (moss-leachen)	1210	2082	Parshevnikov *et al*. (1982)
135	63.50	41.75	Peat-podzolic	Spruce forest (bilberry)	1066	1835	Parshevnikov *et al*. (1982)
136	55.92	38.50	Sod-podzolic	Spruce-linden forest (sedge)	3174	6693	Karpachevsky and Kiseleva (1969)
137	55.92	38.50	Sod-podzolic	Spruce-linden forest (moss)	2953	6228	Karpachevsky and Kiseleva (1969)
138	55.92	38.50	Sod-podzolic	Spruce-linden forest	2624	5533	Karpachevsky and Kiseleva (1969)
139	55.92	38.50	Sod-podzolic	Spruce-linden forest (horse-tail)	2820	5947	Karpachevsky and Kiseleva (1969)
140	55.92	38.50	Sod-podzolic	Spruce-linden forest (fern)	3078	6490	Karpachevsky and Kiseleva (1969)
141	45.00	136.00	Brownzem	Oak forest	4876	9262	Komissarova (1986)
142	45.00	136.00	Brownzem	Cedar forest (grass)	3517	6680	Komissarova (1986)
143	45.00	136.00	Brownzem	Cedar forest (oak)	2830	5376	Komissarova (1986)
144	45.00	136.00	Brownzem	Cedar forest (fir)	3272	6215	Komissarova (1986)
145	45.00	136.00	Brownzem	Spruce-fir forest (cedar)	7061	13412	Komissarova (1986)
146	45.00	136.00	Podbur	Spruce-fir forest (rhododendron)	6775	12868	Komissarova (1986)
147	45.00	136.00	Podbur	Spruce-fir forest (birch)	4876	9262	Komissarova (1986)
148	59.42	30.83	Sod-medium-podzolic	Spruce forest	5069	10934	Gryaz'kin and Tarasov (1989)
149	58.00	33.00	Sod-cryptopodzolic	Spruce forest (30 years)	7000	14930	Grishina *et al*. (1979)
150	58.00	33.00	Sod-cryptopodzolic	Spruce forest (80 years)	4974	10609	Grishina *et al*. (1979)

Table A1: continued.

No.	Location N Latitude	Location E Longitude	Soil	Vegetation	Observed Summer Fs, kg/ha	Estimated ACDF kg/ha	Reference
151	61.67	56.00	Podzolic-strongly	Spruce forest (young)	1159	1865	Frolova (1961)
152	61.67	56.00	Podzolic-strongly	Spruce forest (mature)	2415	3886	Frolova (1961)
153	52.75	26.42	Peat-gleic	Virgin	4493	11590	Baranovsky and Metelitsa (1974)
154	56.42	32.08	Peat-boggy	Spruce forest (oxalis)		9241	Vompersky *et al*. (2000)
155	56.42	32.08	Peat-boggy	Pine forest (bilberry, green-moss)		6519	Vompersky *et al*. (2000)
156	56.42	32.08	Peat-boggy	Pine forest (lichen, green-moss)		5696	Vompersky *et al*. (2000)
157	56.42	32.08	Peat-boggy	Black-alder, grass-fern		4937	Vompersky *et al*. (2000)
158	56.42	32.08	Peat-boggy (drainage)	Black-alder, grass-fern		16329	Vompersky *et al*. (2000)
159	56.42	32.08	Peat-boggy	Ride-hollow complex		4051	Vompersky *et al*. (2000)
160	56.42	32.08	Peat-boggy (drainage)	Ride-hollow complex		7468	Vompersky *et al*. (2000)
162	61.75	31.00	Podzolic	Arable land	2476	4787	Zavarzin and Pogodina (1977)
163	59.00	46.00	Sod-medium-podzolic soil	Rye	4032	9131	Roostalu *et al*. (1970)
164	59.00	46.00	Sod-medium-podzolic soil	Barley	4183	9473	Roostalu *et al*. (1970)
165	61.00	33.00	Sod-podzolic-gley	Pasture	2142	4141	Kozlov (1977)
166	58.00	33.00	Sod-podzolic-contact -gleic	Swede	1856	3958	Grishina and Morgun (1978)
167	58.00	33.00	Sod-medium-podzolic-contact-gleic	Barley	2349	5010	Grishina and Morgun (1978)
168	58.00	33.00	Sod-podzolic	Swede	1804	3848	Grishina and Morgun (1978)
169	58.00	33.00	Sod-podzolic	Swede	2361	5036	Grishina and Morgun (1978)
170	58.00	33.00	Sod-medium-podzolic-contact-gleic	Barley	1846	3937	Grishina and Morgun (1978)
171	58.00	33.00	Sod-strongly-podzolic-contact-gleic	Barley	1782	3802	Grishina and Morgun (1978)
172	58.00	33.00	Crypto-podzolic-deep-gleic	Swede	1522	3246	Grishina and Morgun (1978)
173	58.00	33.00	Crypto-podzolic	Swede	1436	3063	Grishina and Morgun (1978)
174	55.00	29.00	Sod-podzolic	Winter rye+fallow	1166	2724	Shkurinov (1972)
175	55.00	29.00	Sod-podzolic	Winter rye+trefoil	1423	3324	Shkurinov (1972)
176	55.00	29.00	Sod-podzolic	Trefoil (1 year)	1787	4173	Shkurinov (1972)
177	55.00	29.00	Sod-podzolic	Trefoil (2 year)	1668	3895	Shkurinov (1972)
178	55.00	29.00	Sod-podzolic	Flax (long-fibred)	1414	3302	Shkurinov (1972)
179	55.00	29.00	Sod-podzolic	Potato	1754	4097	Shkurinov (1972)
180	55.00	29.00	Sod-podzolic	Maize	1682	3928	Shkurinov (1972)
181	55.00	29.00	Sod-podzolic	Barley	1556	3633	Shkurinov (1972)

Table A1: continued.

No.	Location N Latitude	Location E Longitude	Soil	Vegetation	Observed Summer Fs, kg/ha	Estimated ACDF kg/ha	Reference
182	55.00	29.00	Sod-podzolic	Fallow land	1956	4567	Shkurinov (1972)
183	55.92	36.83	Sod-medium-podzolic	Fallow	640	1311	Makarov (1966)
184	55.92	36.83	Sod-medium-podzolic	Barley	1918	3931	Makarov (1966)
185	55.92	36.83	Sod-medium-podzolic	Alfalfa	1795	3679	Makarov (1966)
186	55.92	36.83	Sod-medium-podzolic	Trifol+timothy-grass	1899	3892	Makarov (1966)
187	55.92	36.83	Sod-medium-podzolic	Oats	1728	3542	Makarov (1966)
188	52.67	25.33	Peat-boggy	Fallow	838	2161	Belkovsky and Reshetnik (1981)
189	52.67	25.33	Peat-boggy	Perrenial grass	1965	5069	Belkovsky and Reshetnik (1981)
190	52.67	25.33	Peat-boggy	Winter rye	1701	4388	Belkovsky and Reshetnik (1981)
191	52.67	25.33	Peat-boggy	Potato	1191	3073	Belkovsky and Reshetnik (1981)
192	54.00	28.00	Peat-boggy	Potato	644	1661	Zimenko and Samsonova (1971)
193	56.08	37.50	Sod-podzolic	Perrenial grass	1192	2428	Bondarev (1965)
194	56.08	37.50	Sod-podzolic	Rye	753	1534	Bondarev (1965)
195	56.08	37.50	Sod-podzolic	Fallow	815	1661	Bondarev (1965)
196	55.42	38.67	Sod-medium-podzolic	Fallow	1318	2779	Makarov and Frenkel' (1956)
197	55.42	38.67	Sod-medium-podzolic	Perrenial grass	3061	6455	Makarov and Frenkel' (1956)
198	55.42	38.67	Sod-medium-podzolic	Winter rye	2491	5254	Makarov and Frenkel' (1956)
199	55.42	38.67	Sod-medium-podzolic	Oats	2753	5805	Makarov and Frenkel' (1956)
200	55.42	38.67	Sod-podzolic	Barley	1766	3725	Makarov and Frenkel' (1956)
201	55.42	38.67	Sod-medium-podzolic	Potato	1882	3969	Makarov and Frenkel' (1956)
202	55.42	38.67	Sod-podzolic	Fallow	1485	3131	Makarov and Frenkel' (1956)
203	56.33	37.42	Humus-peaty-ferrigenous	Perrenial grass	4996	10180	Makarov (1960)
204	56.33	37.42	Humus-peaty-ferrigenous-calcareous	Perrenial grass	4677	9529	Makarov (1960)
205	56.33	37.42	Humus-peaty-ferrigenous-calcareous	Fallow	2884	5875	Makarov (1960)
206	54.00	28.00	Peaty soil	Perrenial grass	672	1568	Zimenko and Samsonova (1971)
207	54.00	28.00	Peaty soil	Grain crops (8 years)	672	1568	Zimenko and Samsonova (1971)
208	54.00	28.00	Peaty soil	Grain crops (20 years)	543	1267	Zimenko and Samsonova (1971)
209	54.00	28.00	Peaty soil	Grain crops (35 years)	423	988	Zimenko and Samsonova (1971)
210	56.67	66.50	Peaty soil	Fallow	1803	2999	Pokotilo and Efimov (1977)
211	56.67	66.50	Peat soil	Perrenial grass	5587	9294	Pokotilo and Efimov (1977)

Table A1: continued.

No.	Location N Latitude	Location E Longitude	Soil	Vegetation	Observed Summer Fs, kg/ha	Estimated ACDF kg/ha	Reference
212	56.67	66.50	Peat soil		1956	3253	Pokotilo and Efimov (1977)
213			Sod-(muck)-gleys	Fallow	5546	9022	
214			Sod-gleic	Potato	1803	2933	
215	61.67	50.83	Sod-medium-podzolic	Trifol	3190	5133	Chebykina (1978)
216	54.83	39.00	Sod-weakly-podzolic	Winter wheat	1748	3729	Panov *et al*. (1984)
217	52.75	26.42	Peat-gleys	Fallow land	3124	8057	Baranovsky and Metelitsa (1974)
218	58.00	33.00	Crypto-podzolic-deep-gleic	Swede	1254	2675	Grishina and Morgun (1978)
219	58.00	33.00	Crypto-podzolic	Swede	1119	2386	Grishina and Morgun (1978)
220	52.75	26.42	Peaty-gleys	Grain crops	4746	12243	Baranovsky and Metelitsa (1974)
221	52.75	26.42	Peat-gleys	Potato	3399	8767	Baranovsky and Metelitsa (1974)
222	56.33	27.42	Peat-gleys	Perrenial grass	4122	8399	Makarov (1958)
223	56.33	27.42	Peat-gleys	Perrenial grass	2792	5689	Makarov (1958)
224	53.00	27.00	Peaty-bog soil	Oaks	2088	4875	Skoropanov *et al*. (1960)
225	56.33	27.42	Peat-gleys	Fallow	1477	3009	Makarov (1958)
226	53.00	27.00	Peat-boggy	Timothy grass	1761	4111	Skoropanov *et al*. (1960)
227	52.75	26.42	Peat-gleys	Perrenial grass	4761	12280	Baranovsky and Metelitsa (1974)
228	58.00	33.00	Sod-podzolic-contact-gleic	Barley	1488	3174	Grishina and Morgun (1978)
229	58.00	33.00	Sod-podzolic	Barley	1494	3186	Grishina and Morgun (1978)
230	54.83	37.58	Grey forest soil	Fallow	564	1210	Ivannikova and Semenova (1988)
231	54.83	37.58	Grey forest soil	Winter wheat	761	1631	Ivannikova and Semenova (1988)
232	54.83	37.58	Grey forest soil	Maize	634	1361	Larionova *et al*. (2000)
233	52.33	104.17	Grey forest soil	Fallow	1041	1580	Pomazkina *et al*. (1996)
234	52.33	104.17	Alluvials	Fallow	903	1371	Pomazkina *et al*. (1996)
235	52.33	104.17	Sod-meadow	Fallow	1196	1815	Pomazkina *et al*. (1996)
236	56.00	90.42	Soil substrate (regenerative)	Grassland	2351	3955	Naumov (1991)
237	56.00	90.42	Meadow-chernozemics	Grassland (mezophithic)	4810	8091	Naumov (1991)
238	56.00	90.42	Chernozem ordinary	Grassland (nature)	3068	5162	Naumov (1991)
239	55.83	65.58	Chernozem leached	Virgin lands (pasture or hayfield)	1116	1943	Krivonos and Yegorov (1983)
240	55.83	65.58	Chernozem leached	Arable (GSU)	806	1404	Krivonos and Yegorov (1983)
241	55.83	65.58	Chernozem leached	Arable (state farm)	632	1100	Krivonos and Yegorov (1983)

Table A1: continued.

No.	Location N Latitude	Location E Longitude	Soil	Vegetation	Observed Summer Fs, kg/ha	Estimated ACDF kg/ha	Reference
242	54.83	66.00	Chernozem leached	Virgin lands (pasture or hayfield)	1960	3412	Krivonos and Yegorov (1983)
243	54.83	66.00	Chernozem leached	Arable (GSU)	946	1646	Krivonos and Yegorov (1983)
244	54.83	66.00	Chernozem leached	Arable (state farm)	815	1419	Krivonos and Yegorov (1983)
246	51.83	107.67	Chestnuts	Wheat	2761	3852	Nimaeva *et al*. (1983)
247	52.58	78.92	Chestnuts	Fallow	1491	2702	
248	52.58	78.92	Chestnuts	Wheat	1476	2676	
249	60.92	132.00	Meadow-chernozemics (frozen)	Virgin	2840	3081	Volotkovskaya and Savinov (1988)
250	60.92	132.00	Meadow-chernozemics (frozen)	Fallow	1960	2126	Volotkovskaya and Savinov (1988)
251	60.92	132.00	Meadow-chernozemics (frozen)	Monolith (watering)	2392	2595	Volotkovskaya and Savinov (1988)
252	60.92	132.00	Meadow-chernozemics (frozen)	Monolith (boghara)	1674	1816	Volotkovskaya and Savinov (1988)
253	60.92	132.00	Meadow-chernozemics (frozen)	Oaks (boghara)	2174	2359	Volotkovskaya and Savinov (1988)
254	55.00	83.00	Chernozem leached	Arable lands	2028	3246	Kiryushin and Danilova (1990)
255	52.58	78.92	Chestnuts	Fallow	1503	2724	
256	52.58	78.92	Chestnuts	Wheat	1486	2694	
257	52.42	38.33	Sod-podzolic	Winter wheat	3592	7576	Makarov (1988)
258	52.42	38.33	Sod-podzolic	Barley	1801	3798	Makarov (1988)
259	52.42	38.33	Sod-podzolic	Fallow	577	1217	Makarov (1988)
260	67.67	33.17	Mountain tundra	Yernik	453	725	Shmakova and Ushakova (2000)
261	67.67	33.17	Mountain tundra	Lichen	154	246	Shmakova and Ushakova (2000)
262	67.67	33.17	Mountain tundra	Voronichnaya	460	736	Shmakova and Ushakova (2000)
263	67.67	33.17	Mountain tundra	Grass-shrubby	276	442	Shmakova and Ushakova (2000)
264	67.67	33.17	Mountain tundra	Juniper	230	368	Shmakova and Ushakova (2000)
265	67.67	33.17	Mountain tundra	Willow	294	471	Shmakova and Ushakova (2000)
266	56.00	48.00	Podzolic (typical, sandy)	Pine forest (25–27 years)	605	1342	Smirnov (1955)
267	56.00	48.00	Podzolic (typical, sandy)	Pine forest (red bilberries, birch, juniper)	892	1978	Smirnov (1955)
268	56.00	48.00	Podzolic gleys peaty	Pine forest (red bilberries, moss)		1750	Smirnov (1955)
269	56.00	48.00	Peats (sphanum)	Pine forest (sphagnum, birch, willow)		1000	Smirnov (1955)
270	56.00	48.00	Sod-podzolic	Spruce forest (complex, 60–80 years)	2880	6385	Smirnov (1955)
271	56.00	48.00	Sod-podzolic	Spruce forest (green moss)	767	1701	Smirnov (1955)
272	56.02	92.83	Chernozems ordinary	Wheat	5040	8478	Bulgakov and Popova (1968)

Table A1: continued.

No.	Location N Latitude	Location E Longitude	Soil	Vegetation	Observed Summer Fs, Kg/ha	Estimated ACDF kg/ha	Reference
273	56.02	92.83	Chernozems leached	Wheat	7007	11787	Bulgakov and Popova (1968)
274	56.02	92.83	Chernozems podzolized	Wheat	5116	8606	Bulgakov and Popova (1968)
275	56.67	66.50	Peats boggy (low, 1.5–2 m)	Drainage	1956	3253	Pokotilo and Efimov (1977)
276	56.67	66.50	Peats boggy (low, 1.5–2 m)	Fallow	2914	4847	Pokotilo and Efimov (1977)
277	56.67	66.50	Peats boggy (low, 1.5–2 m)	Perrenial	5587	9294	Pokotilo and Efimov (1977)
278	53.25	35.92	Chernozems leached	Fallow lands	2061	4642	Mina (1960)
279	53.25	35.92	Chernozems leached	Sparse forest	3302	7439	Mina (1960)
280	53.25	35.92	Chernozems leached	Birch forest (26 years)	3193	7193	Mina (1960)
281	53.25	35.92	Chernozems leached	Oak forest (26 and 60 years)	3358	7564	Mina (1960)
282	53.25	35.92	Chernozems leached	Spruce forest (26 and 60 years)	3008	6776	Mina (1960)
283	53.25	35.92	Chernozems leached	Larch forest (26 years)	3140	7074	Mina (1960)
284	53.25	35.92	Chernozems leached	Pine forest (26 years)	3080	6938	Mina (1960)
285	67.42	64.00	Sod surfacely gleic	Perrenial (1 year after recultivation)	55	64	Stenina (1976)
286	67.42	64.00	Sod surfacely gleic	Perrenial (1 year after recultivation)	85	99	Stenina (1976)
287	67.42	64.00	Sod surfacely gleic	Perrenial (1 year after recultivation)	49	57	Stenina (1976)
288	67.42	64.00	Sod surfacely gleic	Perrenial (1 year after recultivation)	34	40	Stenina (1976)
289	67.42	64.00	Sod surfacely gleic	Perrenial (1 year after recultivation)	17	20	Stenina (1976)
290	52.00	102.00	Chestnut	Virgin lands	2880	3877	
291	52.00	102.00	Chestnut	Arable lands	3149	4239	
292	54.67	83.33	Grey forest soil	Arable land	3420	5473	Sharkov (1987)
293	51.00	40.75	Chernozems ordinary	Sunflower	4692	11010	Turusov (1984)
294	48.67	44.50	Chernozems ???	Crops land	3869	10264	D'yakonova (1961)
295	48.67	44.50	Chernozems ???	Crops land	2255	5984	D'yakonova (1961)
296	52.00	88.00	Mountain forest-meadows (subalpic)	Grassland and pasture	3024	5002	Rukosueva and Gukasyan (1985)
297	52.00	88.00	Mountain taigic brownzems podzolized	Fir forest	2513	4158	Rukosueva and Gukasyan (1985)
298	52.00	88.00	Mountain forest brounozems	Fir forest	4837	8001	Rukosueva and Gukasyan (1985)
299	52.00	88.00	Pale podzolic	Fir forest	3436	5684	Rukosueva and Gukasyan (1985)
300	68.75	161.33	Peaty gleic	Sedge	3680	4107	Fedorov-Davydov and Gilichinsky (1993)
301	68.75	161.33	Peaty gleic (tundra)	Sphagnum	2300	2567	Fedorov-Davydov and Gilichinsky (1993)

Table A1: continued.

No.	Location N Latitude	Location E Longitude	Soil	Vegetation	Observed Summer Fs, Kg/ha	Estimated ACDF kg/ha	Reference
302	68.75	161.33	Podburs tundra (sandy)	Red bilberries, cetraria	2116	2362	Fedorov-Davydov and Gilichinsky (1993)
303	68.75	161.33	Podburs tundra (sandy)	Enpetria	4968	5545	Fedorov-Davydov and Gilichinsky (1993)
304	68.75	161.33	Podburs tundra (sandy, podzolized)	Shrubby, lichen		1439	Fyedorov-Davydov (1998)
305	68.75	161.33	Peaty gleic	Sedge, sphagnum		2026	Fyedorov-Davydov (1998)
306	61.75	34.33	Peats boggy (virgin)	Shrubby, cotton grass, sphagnum	3452	6674	Ikkonen and Sidorova (2000)
307	61.75	34.33	Peats boggy (draining)	Shrubby, cotton grass, sphagnum	6217	12019	Ikkonen and Sidorova (2000)
308	48.67	28.50	Brown forest soil	Spruce forest	736	1843	Shpakivskaya (2000)
309	48.67	28.50	Sod brownzems	Spruce forest	1030	2581	Shpakivskaya (2000)
310	48.67	28.50	Sod brownzems	Spruce forest	488	1221	Shpakivskaya (2000)
311	56.00	85.00	Peat-boggy	Spruce forest (shrubby, sphagnum)	1380	2173	Panikov *et al*. (1995)
312	56.00	85.00	Peat-boggy	Spruce-birch forest (shrubby, sphagnum)	1840	2897	Panikov *et al*. (1995)
313	56.00	85.00	Peat-boggy	Mixed forest (hummocky, sedge)	2300	3621	Panikov *et al*. (1995)
314	57.00	82.00	Peat-boggy	Grassland	4725	7440	Panikov *et al*. (1995)
315	56.97	83.18	Peat-boggy	Spruce-birch forest (shrubby, sphagnum)	2550	4015	Panikov *et al*. (1995)
316	67.33	63.74	Gleyzems tundra	Shrubby, moss-lichen		2292	Zamolodchikov *et al*. (2000)
317	67.33	63.74	Gleyzems peaty tundra	Sedge bog		2359	Zamolodchikov *et al*. (2000)
318	46.42	30.75	Chernozem southern	Grain crops	1040	2757	Lyadova (1975)
319	48.00	44.50	Chestnuts light	Arable lands	2392	6034	Kretinina and Pozhilov (1986)
320	73.25	89.67	Gleyzems tundra	Green-moss lichen and lichen-shrubby	1250	1392	Grishina (1986)
321	53.00	36.08	Chernozem leached	Fallow land (no fertilized)	1325	2985	Koltakova (1975)
322	53.00	36.08	Chernozem leached	Abandoned land	3013	6787	Koltakova (1975)
323	53.00	36.08	Chernozem leached	Field protective shelterbelt	3745	8437	Koltakova (1975)
324	53.00	36.08	Chernozem leached	Fallow land (not fertilized)	1434	3231	Koltakova (1975)
325	53.00	36.08	Chernozem leached	Fallow land (fertilized)	1520	3425	Koltakova (1975)
326	53.00	36.08	Chernozem leached	Winter wheat (not fertilized)	1528	3443	Koltakova (1975)
327	53.00	36.08	Chernozem leached	Winter wheat (fertilized)	1916	4316	Koltakova (1975)
328	53.00	36.08	Chernozem leached	Potato (not fertilized)	1803	4061	Koltakova (1975)
329	53.00	36.08	Chernozem leached	Potato (fertilized)	1991	4486	Koltakova (1975)

Table A1: continued.

No.	Location N Latitude	Location E Longitude	Soil	Vegetation	Observed Summer Fs, Kg/ha	Estimated ACDF kg/ha	Reference
330	54.00	91.00	Chernozem	Wheat	4826	8118	Popova (1968)
331	54.00	91.00	Brownzems	Wheat	2904	4885	Popova (1968)
332	54.00	91.00	Chernozem	Fallow	4952	8330	Popova (1968)
333	54.00	91.00	Chernozem	Fallow (clear)	4100	6897	Popova (1968)
334	54.00	91.00	Meadow chernozemics	Forest	4766	8017	Popova (1968)
335	54.00	91.00	Brownzems	Forest	4697	7901	Popova (1968)
336	51.00	40.75	Chernozems ordinary	Sunflower	1353	3174	Korobov (1989)
337	51.17	71.42	Chestnuts dark	Weat	1760	3136	Mendeshev and Zherdeva (1989)
338	51.17	71.42	Chestnuts dark	Virgin	2830	5042	Mendeshev and Zherdeva (1989)
339	51.17	71.42	Solonetzes meadowish	Arable	1153	2053	Polovitsky and Zhandaev (1973)
340	51.17	71.42	Meadow chestnuts	Arable	1280	2281	Polovitsky and Zhandaev (1973)
341	48.00	44.50	Dark color soils	Fallow	1878	4801	Matskevich (1958)
342	48.00	44.50	Dark color soils	Perrenial grass	2337	5975	Matskevich (1958)
343	48.00	44.50	Dark color soils	Elm	2253	5760	Matskevich (1958)
344	45.33	41.67	Chernozems ordinary micela-calcareous	Maize	7268	19331	Burdyukov *et al*. (1983)
345	51.17	71.42	Chestnuts duck calcareos	Virgin (disturbed)	2420	4310	Emel'yanov (1970)
346	49.67	39.00	Chernozems	Virgin (feather grass, fescue)	2210	5797	Zonn and Alyoshina (1953)
347	49.67	39.00	Chernozems	Oak (stubble)	2668	6998	Zonn and Alyoshina (1953)
348	49.67	39.00	Chernozems	Field protection forest	1564	4102	Zonn and Alyoshina (1953)
349	49.67	39.00	Chernozems	Oak forest (18–20 years)	3312	8687	Zonn and Alyoshina (1953)
350	48.50	35.00	Chernozems ordinary	Fallow	2009	5319	Yaroshevich and Getmanets (1973)
351	48.50	35.00	Chernozems ordinary	Maize	1877	4969	Yaroshevich and Getmanets (1973)
352	48.50	35.00	Chernozems ordinary	Soy	2056	5443	Yaroshevich and Getmanets (1973)
353	48.50	35.00	Chernozems ordinary	Sunflowers	2185	5786	Yaroshevich and Getmanets (1973)
354	53.00	108.00	Chestnuts	Arable	91	138	Chimitdorzhieva *et al*. (1990)
355	73.25	90.58	Soil of spots-medalions	Dreadum-sedge-moss	975	1086	Parinkina (1974)
356	67.92	65.75	Peat-boggy	Grass-sphagnum	2542	2975	Panikov and Zelenev (1992)
357	68.75	168.33	Criozems gleic surface	Larch sparse growth of trees	700	781	Zimov *et al*. (1993)
358	68.75	168.33	Criozems gleic surface	Grassland	1155	1289	Zimov *et al*. (1993)

Table A1: continued.

No.	Location N Latitude	Location E Longitude	Soil	Vegetation	Observed Summer Fs, Kg/ha	Estimated ACDF kg/ha	Reference
359	68.75	168.33	Criozems gleic surface	Larch sparse growth of trees (moss-lichen)	490	547	Zimov *et al*. (1993)
360	68.75	168.33	Criozems gleic surface	Larch sparse growth of trees (moss-lichen)	595	664	Zimov *et al*. (1993)
361	48.56	39.25	Chernozems	Oak, ash-tree, acacia (18 years)	2674	7013	Mina (1957)
362	59.50	40.42	Peaty-humus gleic	Spruce forest	3623	6801	Mina (1957)
363	59.50	40.42	Podzolic	Spruce forest	3613	6782	Mina (1957)
364	64.42	172.50	Podbur tundra			1874	Zamolodchikov and Karelin (2001)
365	65.80	173.35	Podbur tundra			1874	Zamolodchikov and Karelin (2001)
366	73.25	90.59	Podbur tundra			1870	Zamolodchikov and Karelin (2001)
367	72.28	85.75	Podbur tundra			1870	Zamolodchikov and Karelin (2001)
368	70.85	89.90	Podbur tundra			1870	Zamolodchikov and Karelin (2001)
369	71.43	89.23	Podbur tundra			1870	Zamolodchikov and Karelin (2001)
370	73.94	91.90	Podbur tundra			1870	Zamolodchikov and Karelin (2001)
371	67.95	64.67	Podbur tundra			3308	Zamolodchikov and Karelin (2001)
371	67.33	63.73	Podbur tundra			3308	Zamolodchikov and Karelin (2001)
372	67.00	38.00	Podzol ferriginous-illuvial sandy	Pine forest (lichen)	793	1216	Repnevskaya (1967)
373	67.00	38.00	Podzol ferriginous-illuvial sandy	Pine forest (lichen-red bilberry)	1115	1710	Repnevskaya (1967)
374	67.00	38.00	Podzol humus-ferriginous-illuvial sandy-loamy sand	Pine forest (whortleberry)	1217	1866	Repnevskaya (1967)
375	67.00	38.00	Podzol humus-illuvial sandy-loamy-sand	Pine forest (whortleberry), moist	1337	2050	Repnevskaya (1967)

Table A2: The contribution of summer CO_2 flux to ACDF (C_{Fs}) subject to mean annual air temperature.

No.	Soil	Vegetation	Latitude	Longitude	Mean annual air T, °C	C_{Fs} (observ), %	Reference
1	Podbur tundra	Moss-lichen	68.8	168.3	-13.4	90.2	Zamolodchikov and Karelin (2001)
2	Podbur tundra	Moss-lichen	71.5	90.0	-11.8	91.3	Zamolodchikov and Karelin (2001)
3	Podbur tundra	Moss-lichen	65.0	173.0	-7.4	84.2	Zamolodchikov and Karelin (2001)
4	Podbur tundra	Moss-lichen	67.3	63.8	-6.4	91.0	Zamolodchikov and Karelin (2001)
5	Sandy soil	Spruce forest (200 years)	66.4	29.0	2	45.0	
6	Sod-podzolic	Forest mixed	54.8	37.6	4.0	45.6	Lopes de Gerenyu *et al*. (2001)
7	Sod podzolic	Grassland	54.8	37.6	4.0	45.6	Lopes de Gerenyu *et al*. (2001)
8	Grey forest soil	Forest Mixed	54.8	37.6	4.0	48.8	Lopes de Gerenyu *et al*. (2001)
9	Grey forest soil	Grassland	54.8	37.6	4.0	43.1	Lopes de Gerenyu *et al*. (2001)
10	Grey forest soil	Arable	54.8	37.6	4.0	51.6	Lopes de Gerenyu *et al*. (2001)
11	Podzol (iron)	Pine (scots) forest	62.8	31.0	4.4	47.3	Pajary (1995)
12	Podzol (iron)	Pine (scots) forest	62.8	31.0	4.4	51.4	Pajary (1995)
13	Loamy sandy	Beech-spruce forest	49.3	8.6	6.5	35.9	Dörr and Münich (1987)
14	Peat-bog	Low bog	48.8	9.2	6.5	44.0	Adam and Star (1997)
15	Brownerde	Spruce Forest	48.8	9.2	6.5	46.9	Adam and Star (1997)
16	Kolluvisol	Grassland	48.8	9.2	6.5	34.8	Adam and Star (1997)
17		Crops	51.2	0.3	8.4	32.9	Monteith *et al*. (1964)
18		Sweet Chestnut	51.3	1.1	10.5	37.4	Anderson (1973)
19		Beech	51.3	1.1	10.5	40.9	Anderson (1973)

Table A3: The total heterotrophic and autotrophic soil respiration of Russian terrestrial ecosystems.

No.	Soil	Vegetation	No. of studied sites	Mean summer CO_2 flux, kg $ha^{-1}season^{-1}$ (observed)	Total CO_2 flux, kg $ha^{-1}yr^{-1}$ (estimated)		Heterotr. CO_2 flux, kg $ha^{-01}yr^{-1}$ (estimated)		Autotr. CO_2 flux, kg $ha^{-1}yr^{-1}$ (estimated)	
					Mean	Std	Mean	Std	Mean	Std
1	Brownzems	Forest	6	3838	7087	1520	3614	775	3473	745
2	Chernozems leached	Forest	7	3261	7346	553	3747	282	3600	271
3	Chernozems shallow	Forest	4	2554	6700	1905	3417	971	3283	933
4	Gray forest soil	Forest	3	1816	3895	1926	1986	982	1909	944
5	Meadow-chernozemics	Forest	1	2253	5760		2938		2822	
6	Mountein forest	Forest	2	3675	6079	2718	3100	1386	2979	1332
7	Pale podzolic	Forest	1	3436	5684		2899		2785	
8	Peat low moor	Forest	3	1073	2014	532	1027	271	987	261
9	Peat-boggy (Belarus')	Forest	5	1003	2342	1463	1194	746	1147	717
10	Peat-boggy (drainage)	Forest	33	5819	11939	4431	6089	2260	5850	2171
11	Peat-boggy (N-W)	Forest	17	1539	3428	2161	1748	1102	1680	1059
12	Peats transitional moor	Forest	3	1794	3432	2832	1750	1444	1682	1387
13	Peaty-humus gleic	Forest	1	3623	6801		3468		3332	
14	Podbur	Forest	2	5825	11065	2550	5643	1301	5422	1250
15	Podzolics	Forest	6	1470	2542	1469	1297	749	1246	720
16	Podzol	Forest	12	1386	2500	1490	1275	760	1225	730
17	Podzolic gleys peaty	Forest	1		1750		893		858	
18	Sod brownzems	Forest	2	759	1901	961	969	490	931	471
19	Sod-podzolics	Forest	42	2857	6072	2812	3097	1434	2975	1378
20	Gleyzems tundra	Forest (Northern)	3	595	664	117	133	23	531	94
21	Meadow chernozemics	Forest	1	2174	2359		472		1887	
22	Peat-boggy (Siberian)	Forest (Northern)	5	2005	3192	706	638	141	2553	564
23	Podzol humus-illuvial	Forest (Northern)	1	1337	2050		410	0	1640	0
24	Podzol illuvial-humus-ferriginous	Forest (Northern)	8	1154	1828	667	366	133	1462	533
25	Podzolics-peat	Forest (Northern)	1	1066	1835		367		1468	
82	Meadow chernozemics	Forest	1	4766	8017		1603		6414	
26	Chernozems leached	Grassland	7	1776	3775	1547	2265	928	1510	619
27	Chernozem ordinary	Grassland	1	3068	5162		3097		2065	
28	Chernozems	Grassland	1	2210	5797		3478		2319	

Table A3: continued.

No.	Soil	Vegetation	No. of studied sites	Mean summer CO_2 flux, kg $ha^{-1}season^{-1}$ (observed)	Total CO_2 flux, kg $ha^{-1}yr^{-1}$ (estimated) Mean	Std	Heterotr. CO_2 flux, kg $ha^{-01}yr^{-1}$ (estimated) Mean	Std	Autotr. CO_2 flux, kg $ha^{-1}yr^{-1}$ (estimated) Mean	Std
29	Chestnut	Grassland	1	2880	3877		2326		1551	
30	Chestnuts dark	Grassland	1	2830	5042		3025		2017	
31	Chestnuts duck calcareos	Grassland	1	2420	4310		2586		1724	
32	Gleyzems tundra	Grassland	1	1155	1289		773		516	
33	Meadow chernozems	Grassland	1	2337	5975		3585		2390	
34	Gray forest soil	Grassland	3	1956	4195	3196	2517	1918	1678	1279
35	Peats low moor (drained)	Grassland	5	5163	10519	666	6311	400	4207	266
36	Meadow-chernozemics	Grassland	1	4810	8091		4854		3236	
37	Meadow-chernoz. (frozen)	Grassland	1	2302	2498	638	1499	383	999	255
38	Mountain forest-meadow	Grassland	1	3024	5002		3001		2001	
39	Peat-boggy (Siberian)	Grassland	3	5300	8676	1070	5205	642	3470	428
40	Glryzems peaty	Grassland	5	3858	9203	2714	5522	1629	3681	1086
41	Peat-boggy	Grassland	7	1218	2901	1645	1740	987	1160	658
42	Podzolics	Grassland	3	2106	4122	2561	2473	1537	1649	1024
43	Sod-podzolics	Grassland	15	2888	5974	2509	3585	1505	2390	1004
44	Sod-podzolic-gleys	Grassland	1	2142	4141		2484		1656	
46	Sod-gleys	Tundra	7	362	470	705	127	191	297	445
47	Gleyzems peaty tundra	Tundra	5	2841	2781	753	965	239	2251	559
48	Gleyzems tundra	Tundra	2		1798		553		1289	
49	Mountain tundra	Tundra	6	311	515	203	149	59	349	137
50	Soil of spots-medalions	Tundra	1	975	1017		1086		2534	
51	Podburs tundra	Tundra	3		2937		935		2181	
52	Gleyzems tundra	Tundra	3		2190		657		1533	
53	Brownzems	Cropland	1	2904	4979		3224		1661	
54	Chernozems leached	Cropland	10	1947	3646	3182	2436	2067	1255	1065
55	Chernozems ordinary	Cropland	7	2745	6324	2449	4165	1713	2146	883
56	Chernoz. ordin. micela-calcar.	Cropland	1	7268	20742		12758		6573	
57	Chernozems podzolized	Cropland	1	5116	8771		5680		2926	
58	Chernozems shallow	Cropland	3	4626	7931	789	5136	511	2646	263

Table A3: continued.

No.	Soil	Vegetation	No. of studied sites	Mean summer CO_2 flux, kg $ha^{-1}season^{-1}$ (observed)	Total CO_2 flux, kg $ha^{-1}yr^{-1}$ (estimated)		Heterotr. CO_2 flux, kg $ha^{-01}yr^{-1}$ (estimated)		Autotr. CO_2 flux, kg $ha^{-1}yr^{-1}$ (estimated)	
					Mean	Std	Mean	Std	Mean	Std
59	Chernozems southern	Cropland	3	2388	6680	3814	4181	2485	2154	1280
60	Chestnuts	Cropland	7	1708	2809	1427	1794	863	924	445
61	Chestnuts dark	Cropland	1	1760	3140		2070		1066	
62	Chestnuts light	Cropland	1	2392	5814		3983		2052	
63	Gleyzems peaty	Cropland	3	3207	7830	4595	5284	3078	2722	1586
64	Grey forest soil	Cropland	9	1311	2484	1556	1671	1008	861	519
65	Meadow chestnuts	Cropland	1	1280	2284		1505		775	
66	Peat-boggy	Cropland	9	1552	3630	4336	2493	3026	1284	1559
67	Peats low moor (drained)	Cropland	1	2298	4642		3199		1648	
68	Podzolic	Cropland	5	1667	3305	1014	2264	668	1167	344
69	Podzolics deep-gleic	Cropland	3	1497	3051	471	2107	325	1085	167
70	Sod podzolics gley	Cropland		2039	4156	680	2870	469	1478	242
71	Sod-gleic	Cropland	2	3674	6157		3945	0	2032	
72	Sod-podzolic	Cropland	47	2071	4181	2034	2874	1406	1480	724
73	Sod-surfacely gleic	Cropland	1	837	1086		646		333	
74	Solonetzes meadowish	Cropland	1	1153	2056		1355		698	
75	Alluvials	Fallow	1	903	1442		1371		706	
76	Meadow-chernozemics (frozen)	Fallow	1	1960	2146		2126		1095	
77	Meadow-chernozems	Fallow	1	1878	4667		4801		2473	
78	Peat boggy (Belarus')	Fallow	2	710	1794	459	1830	468	943	241
79	Peat boggy (Sibir')	Fallow	2	2359	4013	1336	3923	1307	2021	673
80	Peats low moor (drained)	Fallow	1	2884	5669		5875		3027	
81	Sod-meadow	Fallow	2	1196	1910	4434	1815	4305	935	2218

Table A4: The root/rizosphere contributions (RC) to total respiration by vegetation type and experimental approach.

No.	Vegetation type	Species (or soil)	Experimental setting	Approach	RC, %	Time step	Reference
1	Birch woodlands	Abies	-		30	Annual	Leith and Ovellete (1962)
2	Birch woodlands	Betula	Container	Root excude	69	Summer	Minderman and Vulto (1983)
3	Birch woodlands	Betula	Container	Root excude	33	Winter	Minderman and Vulto (1983)
4	Birch woodlands	Betula	Container	Root excude	50	Winter	Minderman and Vulto (1983)
5	Deciduous woodland	Castenea/fagus	Field	Comp.integr.	20	Annual	Anderson (1973)
6		Fagus	Field	Comp.integr.	5	Annual	Phillipson *et al.* (1975)
7		Fagus	Field	Root excude	40	Daily	Brumme (1995)
8		Fagus/Abies	Field	-	42	Annual	Nakane (1980)
9		Fagus/Picea	Field	Iso ^{14}C	40	Monthly	Dörr and Münich (1987)
10		Fagus/Picea	Field	Iso ^{14}C	75	Summer	Dörr and Münich (1986)
11		Fagus/Picea	Field	Iso ^{14}C	25	Winter	Dörr and Münich (1986)
12		Liriodendron	Field	Comp.integr.	22	Annual	Edwards and Sollings (1973)
13		Liriodendron	Field	Comp.integr.	36	Annual	Edwards and Sollings (1973)
14		Liriodendron	Field	Comp.integr.	77	Annual	Edwards and Harris (1977)
15		Nothofagus	Field	Comp.integr.	23	Daily	Tate *et al.* (1993)
16		Qercus/Acer	Field	Root excude	33	Annual	Bowden *et al.* (1993)
17		Qercus	Field	Root excude	84	Daily	Edwards and Ross-Todd (1983)
18		Qercus	Lab	Comp.integr.	40	Daily	De Bois (1974)
19		Qercus	Field	-	48	Annual	Kira (1978)
20		Qercus	Field	-	50	Annual	Nakane and Kira (1978)
21		Qercus	Field	Comp.integr.	6	Daily	Coleman (1973)
22		Qercus	Field	Comp.integr.	11	Daily	Coleman (1973)
23		Qercus	Field	Root excude	90	Annual	Thierron and Laudelout (1996)
24		Qercus	Field	-	48	Annual	Nakane (1980)
25		Qercus	Field	-	52	Annual	Nakane (1980)
26		Qercus	Field	Root excude	52	Summer	Kelting *et al.* (1998)
27		Pinus	Field	Root excude	45	Weekly	Wiant (1967a, b)
28		Pinus	Field	Root excude	66	Weekly	Wiant (1967a, b)
29		Pinus eliottii	Field	Root excude	51	Weekly	Ewel *et al.* (1987)
30		Pinus eliottii	Field	Root excude	62	Weekly	Ewel *et al.* (1987)
31		Pinus taeda	Field	Root excude	67	December	Edwards (1991)
32		Pinus taeda	Field	Root excude	78	March	Edwards (1991)

Table A4: continued.

No.	Vegetation type	Species (or soil)	Experimental setting	Approach	RC, %	Time step	Reference
33		Pinus taeda	Field	Root excude	54	May	Edwards (1991)
34		Pinus taeda	Field	Root excude	67	August	Edwards (1991)
35		Pinus taeda	Field	Iso ^{13}C	49	Daily	Andrews *et al*. (1997)
36		Pinus resinosa	Field	Root excude	40	Annual	Haynes and Gower (1995)
37		Pinus resinosa	Field	Root excude	65	Annual	Haynes and Gower (1995)
38		Pinus densiflora	Field	Root excude	47	Annual	Nakane *et al*. (1983)
39		Pinus densiflora	Field	Root excude	51	Annual	Nakane *et al*. (1983)
40		Pinus ponderosa	Field	Comp.integr.	90	Daily	Johnson *et al*. (1994)
41		Populus euramerican	Field	Iso ^{14}C	20	Daily	Horwath *et al*. (1994)
42		Populus tremuloides	Field	Comp.integr.	60	Annual	Russel and Voroney (1998)
43		Pseudotsuga	Chamber	Iso $^{13}C/^{18}O$	28	April	Lin *et al*. (1999)
44		Pseudotsuga	Chamber	Iso $^{13}C/^{18}O$	12	June	Lin *et al*. (1999)
45		Pseudotsuga	Chamber	Iso $^{13}C/^{18}O$	25	August	Lin *et al*. (1999)
46		Pseudotsuga	Chamber	Iso $^{13}C/^{18}O$	30	October	Lin *et al*. (1999)
47		Guercus/Carya	Field	Comp.integr.	55	Daily	Garret and Cox (1973)
48		Tsuga	Field	Root excude	37	Annual	Wiant (1967a, b)
49		Tsuga	Field	Root excude	52	Annual	Wiant (1967a, b)
50	Broad-leaved		Field	Root excude	51	Annual	Nakane *et al*. (1996)
51	Hardwood		Field	Root excude	13	Annual	Catricala *et al*. (1997)
52	Hardwood		Field	Root excude	17	Annual	Catricala *et al*. (1997)
53	N. Hardwood		Lab.	Comp.integr.	20	Daily	Hendrickson and Robinson (1984)
54	N. Hardwood		Lab.	Comp.integr.	43	Daily	Hendrickson and Robinson (1984)
55	N. Hardwood		Lab.	Comp.integr.	58	Daily	Hendrickson and Robinson (1984)
56	Tropical dicidous		Field	Comp.integr.	50.5	Daily	Behera *et al*. (1990)
57	Tropical forest		Field	Comp.integr.	55	Annual	Trumbore *et al*. (1995)
58	Tropical forest		Field	Comp.integr.	43	Annual	Trumbore *et al*. (1995)
59	Tropical forest		Field	Comp.integr.	49	Annual	Nakane (1980)
60	Deciduose woodland				35	Annual	Mina (1960)
61	Beech woodlands				30	Annual	
62	Pinus echinata				50	Annual	Witcamp and Frank (1969)
63	Spruce forest				70	Summer	Molchanov (1990)
64	Spruce forest				40	Autumn	Molchanov (1990)

Table A4: continued.

No.	Vegetation type	Species (or soil)	Experimental setting	Approach	RC, %	Time step	Reference
65	Mixed forest		Profile		39	Vegetation	Larionova *et al*. (1998)
66	Mixed forest		Chamber		23	Vegetation	Larionova *et al*. (1998)
67		Picea mariana	Field	Comp.integr.	54	Summer	
68		Picea mariana	Field	Comp.integr.	6	Daily	
69		Picea mariana	Field	Comp.integr.	80	Daily	
70		Picea mariana	Field	Comp.integr.	43	Daily	
71		Picea mariana	Field	Comp.integr.	82	Annual	Flanagan and Van Cleve (1977)
72		Picea mariana	Field	Comp.integr.	80	Annual	Flanagan and Van Cleve (1977)
73		Picea mariana	Field	Comp.integr.	90	Annual	Flanagan and Van Cleve (1977)
74	Tall grass prairie		Field	Comp.integr.	40	Annual	Kucera and Kirkham (1971)
75	Pasture grass		Field	Comp.integr.	53	Annual	Robertson *et al*. (1995)
76	Bermuda grass		Lab	Izo- C4/c3	40	Annual	Robinson and Scrimgeour (1995)
77	Bermuda grass		Lab	Izo- C4/c3	100	Annual	Robinson and Scrimgeour (1995)
78	Grass		Field	Iso ^{14}C	10	Monthly	Dörr and Münich (1987)
79	Grass		Field	Iso ^{14}C	98	Summer	Dörr and Münich (1986)
80	Grass		Field	Iso ^{14}C	80	Winter	Dörr and Münich (1986)
81		Alopecurus/Festuca	Field	Comp.integr.	37		Glosser and Tesarova (1978)
82		Alopecurus/Festuca	Field	Comp.integr.	60		Glosser and Tesarova (1978)
83		Salix/Saxifraga	Field	Comp.integr.	10		Nakatsubo *et al*. (1998)
84		Salix/Saxifraga	Field	Comp.integr.	50		Nakatsubo *et al*. (1998)
85	Oil palm planting		Field	Root excude	30	Annual	Lamande *et al*. (1996)
86	Oil palm planting		Field	Root excude	80	Annual	Lamande *et al*. (1996)
87	Grassland, Avena sativa				33		Lundegardh (1927)
88	Grassland				13		Coleman (1973)
89	Grassland				17		Coleman (1973)
90	Grassland	Sod-podzolic			33	Warm	Larionova *et al*. (2003)
91	Grassland	Sod-podzolic			25	Cold	Larionova *et al*. (2003)
92	Grassland (goldenrod)				48	Warm	Yoneda and Okata (1987)
93	Grassland (goldenrod)				25	Cold	Yoneda and Okata (1987)
94	Grassland	Grey forest		Profile	28	Vegetation	Larionova *et al*. (1998)
95	Grassland	Grey forest		Chamber	10	Vegetation	Larionova *et al*. (1998)
96	Pasture			Iso ^{14}C	52		Kuzyakov *et al*. (1999)

Table A4: continued.

No.	Vegetation tpe	Species (or soil)	Experimental stting	Approach	RC, %	Time step	References
97	Wheat/Barley		Field/lab	Iso ^{14}C	75	Monthly	Swinnen (1994)
98	Wheat/Barley		Field/lab	Iso ^{14}C	95	Monthly	Swinnen (1994)
99		Zea	Field	Iso-C4/C3	35	Growing	Rochette and Flanagan (1997)
100		Zea	Field	Iso-C4/C3	40	Growing	Rochette and Flanagan (1997)
101		Zea	Field	Iso-C4/C3	9	Non-growing	Rochette and Flanagan (1997)
102		Zea	Field	Iso-C4/C3	10	Growing	Rochette *et al*. (1999)
103		Zea	Field	Iso-C4/C3	28	Growing	Rochette *et al*. (1999)
104		Zea	Field	Iso-C4/C3	42	Growing	Rochette *et al*. (1999)
105		Zea	Field	Iso-C4/C3	18	Growing	Rochette *et al*. (1999)
106		Zea	Field	Iso-C4/C3	7	Growing	Rochette *et al*. (1999)
107	Arable	Grey forest	Profile		33	Annual	Larionova *et al*. (1998)
108	Arable	Grey forest	Chamber		16	Annual	Larionova *et al*. (1998)
109	Weat		Field/lab	Iso ^{14}C	75	Monthly	Kuzyakov and Domansky (2000)
110	Barley		Field/lab	Iso ^{14}C	26	Monthly	Kuzyakov and Domansky (2000)
111	Arctic tundra		Field	Comp.integr.	50	Annual	Billings *et al*. (1977)
112	Arctic tundra		Field	Comp.integr.	90	Annual	Billings *et al*. (1977)
113	Tundra, Dupontia fisheri				33		Bunnel and Scoullar (1975)
114	Tundra, Dupontia fisheri				70		Bunnel and Scoullar (1975)
115	Heatland, Calluna vulgaris				70		
116	Organic soil				40	Growing	Silvola *et al*. (1996)

Table A5: Total heterotrophic and autotrophic annual carbon dioxide flux from Russian soils.

No.	Soil	Summer CO_2 evolution rate (observed), mean Es, $gCm^{-2}hour^{-1}$	Summer CO_2 flux (observed), mean Fs, $kgCm^{-2}hour^{-1}$	Total annual CO_2 flux (ACDF) (polinom. mod.) $kgCha^{-1}year^{-1}$	Heterotr. Resp. HACDF (polinom. mod.) $kgCha^{-1}year^{-1}$	Autotr. Resp. AACDF (polinom. mod.) $kgCha^{-1}year^{-1}$
1	Alluvials	1.0	903	1371	1371	706
2	Chernozems	2.4	2210	5797	3478	2319
3	Chernozems ordinary micela-calcareous	7.9	7268	19331	12758	6573
4	Chernozems podzolized	5.6	5116	8606	5680	2926
5	Chernozems southern	2.6	2388	6335	4181	2154
6	Chestnuts duck calcareos	2.6	2420	4310	2586	1724
7	Chestnuts light	2.6	2392	6034	3983	2052
8	Gleyzems peaty tundra	3.5	2841	3216	965	2251
9	Mountain forest-meadow	3.3	3024	5002	3001	2001
10	Mountain tundra	0.3	311	498	149	349
11	Mountein forest	4.0	3675	6079	3100	2979
12	Pale podzolic	3.7	3436	5684	2899	2785
13	Peats transitional moor	2.0	1794	3432	1750	1682
14	Peaty-humus gleic	3.9	3623	6801	3468	3332
15	Podbur	6.3	5825	11065	5643	5422
16	Podburs tundra			3115	935	2181
17	Podzol	1.6	1386	2500	1275	1225
18	Podzol humus-illuvial	1.5	1337	2050	410	1640
19	Podzol illuvial-humus-ferriginous	1.3	1154	1828	366	1462
20	Podzolics	1.74	1599	2878	1559	1319
21	Podzolic gleys peaty			1750	893	858
22	Podzolics deep-gleic	1.6	1497	3192	2107	1085
23	Podzolics-peat	1.2	1066	1835	367	1468
24	Sod brownzems	0.8	759	1901	969	931
25	Sod podzolics gley	2.2	2039	4348	2870	1478
26	Sod-gleic	4.0	3674	5977	3945	2032
27	Sod-gleys	0.91	362	424	127	297
28	Sod-meadow	1.3	1196	1815	1815	935
29	Sod-podzolic-gleys	2.3	2142	4141	2484	1656

Table A5: continued.

No.	Soil	Summer CO_2 evolution rate (observed), mean Es, $gCm^{-2}hour^{-1}$	Summer CO_2 flux (observed), mean Fs, $kgCm^{-2}hour^{-1}$	Total annual CO_2 flux (ACDF) (polinom. mod.) $kgCha^{-1}year^{-1}$	Heterotr. Resp. HACDF (polinom. mod.) $kgCha^{-1}year^{-1}$	Autotr. Resp. AACDF (polinom. mod.) $kgCha^{-1}year^{-1}$
30	Sod-surfacely gleic	0.9	837	980	646	333
31	Soil of spots-medalions	3.9	975	1086	1086	2534
32	Solonetzes meadowish	1.3	1153	2053	1355	698
33	Meadow chestnuts	1.4	1280	2281	1505	775
36	Sod-podzolics	2.90	2702	5722	3086	2635
37	Brownzems	4.4	4081	7490	3966	3524
38	Chernozems leached	2.33	2144	4282	2632	1650
39	Chernozems ordinary	3.04	2793	6139	4005	2134
40	Chernozems shallow	4.62	4253	7587	4827	2760
41	Chestnuts	2.4	2224	3228	2028	1200
42	Chestnuts dark	2.0	1846	3288	2146	1142
43	Gleyzems peaty (Southern taiga)	4.2	3852	9191	5519	3672
44	Gleyzems tundra (Northern taiga)	1.1	752	839	312	527
45	Gleyzems tundra (Tundra)			10516	595	1411
46	Grey forest soil	1.7	1601	3309	1892	1416
47	Meadow chernozemics (Southern)	5.22	4788	8054	3229	4825
48	Meadow chernozems (steepe)	1.22	1909	4881	4710	2472
49	Meadow-chernozemics (Northern)	2.21	2083	2260	1193	1538
50	Peat-boggy (Siberian)	2.25	2073	3305	733	2573
51	Peat boggy (North-west)	2.42	2223	4790	2443	2347
52	Peats low moor	1.25	1155	2186	1160	1056
53	Peat-boggy (Belarus')	1.09	1006	2352	1209	1147
54	Volcanic ash			6192	3158	3034
55	Brownzems (correct-med)	3.7	3394	6321	3370	2951

Table A6: Total heterotrophic, autotrophic ACDF and corresponding classes for Russian soils (in accordance with the soil map of Russia).

No.	Name of soil	Total annual CO_2 flux ACDF, (polinom. mod.) kg C $ha^{-1}year^{-1}$	Class	Heterotr. annual CO_2 flux HACDF, (polinom. mod.) kg C $ha^{-1}year^{-1}$	Class	Autotr. annual CO_2 flux AACDF, (polinom. mod.) kg C $ha^{-1}year^{-1}$	Class
1	Alluvials acid	2077	3	1371	4	706	3
2	Alluvials meadow	2077	3	1371	4	706	3
3	Alluvials swamp meadow	2077	3	1371	4	706	3
4	Arctic (Cryozems)	498	1	149	1	349	2
5	Brownish-dark-grey forest	3309	5	1892	4	1416	4
6	Browns	2053	4	1355	4	698	3
7	Browns solonetzic and solonchacous	2053	4	1355	4	698	3
8	Brownzems acid	6321	7	3370	6	2951	6
9	Brownzems acid podzolized	6321	7	3370	6	2951	6
10	Brownzems gleyic and gley	6321	7	3370	6	2951	6
11	Brownzems raw-humic	6321	7	3370	6	2951	6
12	Brownzems raw-humic gley	6321	7	3370	6	2951	6
13	Brownzems raw-humic illuvial-humic	6321	7	3370	6	2951	6
14	Brownzems weakly-unsaturated	6321	7	3370	6	2951	6
15	Brownzems weakly-unsaturated podzolized	6321	7	3370	6	2951	6
16	Chernozems compact	5797	6	3478	6	2319	6
17	Chernozems deeply-effer., non-calc.on coarse par.mat.	4282	6	2632	5	1650	5
18	Chernozems leached	4282	6	2632	5	1650	5
19	Chernozems leached glossic	4282	6	2632	5	1650	5
20	Chernozems ordinary	6139	7	4005	7	2134	6
21	Chernozems ordinary glossic	6139	7	4005	7	2134	6
22	Chernozems podzolized	8606	8	5680	7	2926	6
23	Chernozems residual-calcareous	6139	7	4005	7	2134	6
24	Chernozems shallow	7587	7	4827	7	2760	6
25	Chernozems solonetzic	6335	7	4181	7	2154	6
26	Chernozems southern glossic	6335	7	4181	7	2154	6
27	Chernozems southern	6335	7	4181	7	2154	6
28	Chernozems southern and ordinary mycelial-calcareous	12833	9	8470	9	4363	8
29	Chernozems typical	6139	7	4005	7	2134	6

Table A6: continued.

No.	Name of soil	Total annual CO_2 flux ACDF, (polinom. mod.) kg C ha^{-1}year^{-1}	Class	Heterotr. annual CO_2 flux HACDF, (polinom. mod.) kg C ha^{-1}year^{-1}	Class	Autotr. annual CO_2 flux AACDF, (polinom. mod.) kg C ha^{-1}year^{-1}	Class
30	Chernozems washed	4282	6	2632	5	1650	5
31	Chestnuts	3228	5	2028	5	1200	4
32	Chestnuts leached	3228	5	2028	5	1200	4
33	Chestnuts solonetzic and solonchakous	3228	5	2028	5	1200	4
34	Dark chestnuts	3288	5	2146	5	1142	4
35	Dark chestnuts deep	4310	6	2586	5	1724	5
36	Dark-grey forest	3309	5	1892	4	1416	4
37	Glaciers		10		10		10
38	Gley-podzolics	1750	3	893	3	858	3
39	Gley-podzolics with the second bleached horizon	1750	3	893	3	858	3
40	Gleyzems peaty and peaty-humic tundra	3216	5	965	3	2251	6
41	Gleyzems and weak-gley humic tundra	839	2	312	2	527	2
42	Gleyzems arctic	498	1	149	1	349	2
43	Gleyzems differentiated peaty-humic and peat tundra	3216	5	965	3	2251	6
44	Gleyzems muck	3216	5	965	3	2251	6
45	Gleyzems peaty and peat boggy	839	2	312	2	527	2
46	Gleyzems peaty-muck taiga (North)	3216	5	965	3	2251	6
46a	Gleyzems peaty-muck taiga (Southern taiga)	9191	8	5519	7	3672	7
47	Gleyzems shallow and deep peat tundra	839	2	312	2	527	2
48	Gleyzems taiga	839	2	312	2	527	2
49	Gleyzems taiga differentiated	839	2	312	2	527	2
50	Gleyzems weak-gley peaty-humic taiga (North)	3216	5	965	3	2251	6
50a	Gleyzems weak-gley peaty-humic taiga (Southern taiga)	9191	8	5519	7	3672	7
51	Granuzems	839	2	312	2	527	2
52	Grey-pales	5684	6	2899	5	2785	6
53	Greys forest	3309	5	1892	4	1416	4
54	Greys forest gleyic and gley	3309	5	1892	4	1416	4
55	Greys forest non-podzolized	3309	5	1892	4	1416	4
56	Greys forest solodic	3309	5	1892	4	1416	4

Table A6: continued.

No.	Name of soil	Total annual CO_2 flux ACDF, (polinom. mod.) kg C $ha^{-1}year^{-1}$	Class	Heterotr. annual CO_2 flux HACDF, (polinom. mod.) kg C $ha^{-1}year^{-1}$	Class	Autotr. annual CO_2 flux AACDF, (polinom. mod.) kg C $ha^{-1}year^{-1}$	Class
57	Greys forest with the second humic horizon	3309	5	1892	4	1416	4
58	Light chestnuts solonetzic and solonchakous	6034	7	3983	7	2052	6
59	Light-greys forest	3309	5	1892	4	1416	4
60	Lithozems	498	1	149	1	349	2
61	Marshy saline and solonetzic	2053	4	1355	4	698	3
62	Meadow-boggies	5977	6	3945	6	2032	6
63	Meadow-boggies solonetzic and solonchakous	4881	6	4710	7	2472	6
64	Meadow-chernozemics (North)	2260	4	1193	4	1538	5
64a	Meadow-chernozemics (South)	8054	8	3229	6	4825	8
64b	Meadow-chernozemics (Steppe)	4881	6	4710	7	2472	6
65	Meadow-chernozemics calcareous (South)	8054	8	3229	6	4825	8
65a	Meadow-chernozemics calcareous (Steppe)	4881	6	4710	7	2472	6
66	Meadow-chernozemics leached (South)	8054	8	3229	6	4825	8
66a	Meadow-chernozemics leached (Steppe)	4881	6	4710	7	2472	6
67	Meadow-chernozemics solonetzic and solonchakous	4881	6	4710	7	2472	6
68	Meadow-chernozem-likes "Amur prairie"	2750	4	1815	4	935	3
69	Meadow-chestnuts solonetzic	2281	4	1505	4	775	3
70	Meadows	2750	4	1815	4	935	3
71	Meadows differentiated (and solodic)	2750	4	1815	4	935	3
72	Meadows solonetzic and solonchakous	2281	4	1505	4	775	3
73	Mountain forest chernozemic	6079	7	3100	6	2979	6
74	Mountain forest-meadows	5002	7	3001	6	2001	6
75	Mountain primitive	498	1	149	1	349	2
76	Mountain-meadow sods	5002	6	3001	6	2001	6
77	Muck-calcareouses	3216	5	965	3	2251	6
78	Muck-calcareouses tundra	3216	5	965	3	2251	6
79	Pales calcareouses	5684	6	2899	5	2785	6
80	Pales mucky	5684	6	2899	5	2785	6
81	Pales podzolized	5684	6	2899	5	2785	6

Table A6: continued.

No.	Name of soil	Total annual CO_2 flux ACDF, (polinom. mod.) kg C $ha^{-1}year^{-1}$	Class	Heterotr. annual CO_2 flux HACDF, (polinom. mod.) kg C $ha^{-1}year^{-1}$	Class	Autotr. annual CO_2 flux AACDF, (polinom. mod.) kg C $ha^{-1}year^{-1}$	Class
82	Pales solodic	5684	6	2899	5	2785	6
83	Pales typical	5684	6	2899	5	2785	6
84	Peat-ashes bandding boggy	3305	5	733	3	2573	6
85	Peats boggy (without subdivision), North	3305	5	733	3	2573	6
85a	Peats boggy (without subdivision), South	4790	6	2443	5	2347	6
86	Peats high moor (North)	3305	5	733	3	2573	6
86a	Peats high moor (South)	2352		1209		1147	
87	Peats low moor	2186	4	1160	4	1056	4
88	Peats transitional moor	3432	5	1750	4	1682	5
89	Pine forest sands	2500	4	1275	4	1225	4
90	Podburs taiga (without subdivision), North	3115	5	935	3	2181	6
90a	Podburs taiga (without subdivision), South	11065	9	5643	7	5422	9
91	Podburs dark tundra	3115	5	935	3	2181	6
92	Podburs dry-peaty	3115	5	935	3	2181	6
93	Podburs light tundra	3115	5	935	3	2181	6
94	Podburs ochric	3115	5	935	3	2181	6
95	Podburs tundra (without subdivision)	3115	5	935	3	2181	6
96	Podzolic-gleys peat and peaty	1750	3	893	3	858	3
97	Podzolics	2878	4	1559	4	1319	4
98	Podzolics deep-gleyic and gley	3192	5	2107	5	1085	4
99	Podzolics residual-calcareous	2878	4	1559	4	1319	4
100	Podzolics surfacely-gleyic	3192	5	2107	5	1085	4
101	Podzolics with the second bleached horizon	2878	4	1559	4	1319	4
102	Podzols dry-peaty	2500	4	1275	4	1225	4
103	Podzols gleyic	2500	4	1275	4	1225	4
104	Podzols humic-illuvial	2050	4	410	2	1640	5
105	Podzols illuvial-ferrugenous	1828	4	366	2	1462	4
106	Podzols illuvial-humic-ferrugenous (without subdivision)	1828	4	366	2	1462	4
107	Podzols ochric	2500	4	1275	4	1225	4

Table A6: continued.

No.	Name of soil	Total annual CO_2 flux ACDF, (polinom. mod.) kg C ha^{-1}year^{-1}	Class	Heterotr. annual CO_2 flux HACDF, (polinom. mod.) kg C ha^{-1}year^{-1}	Class	Autotr. annual CO_2 flux AACDF, (polinom. mod.) kg C ha^{-1}year^{-1}	Class
108	Podzols with the second bleached horizon	2500	4	1275	4	1225	4
109	Rocks outcrop		1		1		1
110	Sands		10		10		10
111	Sod-(muck-) gleys	4348	6	2870	5	1478	4
112	Sod-brownzems acid	1901	3	969	3	931	3
113	Sod-brownzems ferrugenous	1901	3	969	3	931	3
114	Sod-brownzems weakly-unsaturated and saturated	1901	3	969	3	931	3
115	Sod-calcareouses	2750	4	1815	4	935	4
116	Sod-gleys podzolized	4348	6	2870	5	1478	4
117	Sod-pale-podzolics and podzolized-brownzems	5722	6	3086	6	2635	5
118	Sod-pale-podzolics podzolized-brownzems deepgleyic and gley	5722	6	3086	6	2635	5
119	Sod-podzolic-gleys	4348	6	2870	5	1478	4
120	Sod-podzolic-gleys with the second humic horizon	4348	6	2870	5	1478	4
121	Sod-podzolics	5722	6	3086	6	2635	5
122	Sod-podzolics deep gley and gleyic	4348	6	2870	5	1478	4
123	Sod-podzolics illuvial-ferrugenous	5722	6	3086	6	2635	5
124	Sod-podzolics residual-calcareous	5722	6	3086	6	2635	5
125	Sod-podzolics surfacely-gleyic	4348	4	2870	5	1478	4
126	Sod-podzolics with the second humic horizon	5722	6	3086	6	2635	5
127	Sod-podzolics with the second humic horizon deep-gleyic	5722	6	3086	6	2635	5
128	Soils of spots (saline, arctic and tundra)	498	1	149	1	349	2
129	Solonchaks typic	2053	3	1355	4	698	3
130	Solonetzes	2053	3	1355	4	698	3
131	Solonetzes meadowish	2053	3	1355	4	698	3
132	Solonetzes meadowous	2053	3	1355	4	698	3
133	Taiga peaty-muck high-humic non-gleyic	6801	7	3468	6	3332	7
134	Volcanics banding-ashed	6192	7	3158	6	3034	7
135	Volcanics banding-ochric	6192	7	3158	6	3034	7
136	Volcanics dry-peaty	6192	7	3158	6	3034	7

Table A6: continued.

No.	Name of soil	Total annual CO_2 flux ACDF, (polinom. mod.)		Heterotr. annual CO_2 flux HACDF, (polinom. mod.)		Autotr. annual CO_2 flux AACDF, (polinom. mod.)	
		kg C $ha^{-1}year^{-1}$	Class	kg C $ha^{-1}year^{-1}$	Class	kg C $ha^{-1}year^{-1}$	Class
137	Volcanics illuvial-humic tundra	6192	7	3158	6	3034	7
138	Volcanics ochric (including podzolized)	6192	7	3158	6	3034	7
139	Volcanics podzolized-ochric	6192	7	3158	6	3034	7
	(blank)		10		10		10